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THE PATHOLOGY OF CHRONIC TRAUMATIC HEMOTHORAX

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ALTHOUGH much has been said and written by military surgeons of World War II on the management of hemothorax, certain features have been left untouched. They seem very important in completing the clinical picture as we find it, and it is proposed, therefore, to point these out in some detail.

By chronic, traumatic hemothorax is meant a hemothorax that is not reducible by thoracentesis, even though fresh blood has ceased to enter the pleura and hemostasis has been achieved. A neglected accumulation of intrapleural blood that is satisfactorily aspirable is not considered chronic. A chronic hemothorax is usually an organizing hemothorax, because it is the clotting and its inevitable sequel, organization, that renders the process unreducible by aspiration. As will be seen in the course of this discussion, this term is inadequate, since the really important element in the process is fibrin, whether it is derived from blood spilled into the pleura, or exudate formed by the pleura, or deposited there in some other manner. Due to the accepted use of the term, however, substitution of some other term such as fibrinothorax is not intended.

Organizing hemothorax of massive character will result in a fibrothorax, or will suppurate. Spontaneous resorption of more than moderate amounts of accumulated clotted blood or fibrin probably does not occur without recognizable sequel. There is, however, at least one condition, easily confusable with organizing hemothorax and pathogenetically related to it, which deserves mention. This condition in its pure form results from a grossly infolded and distorted lung without significant pleural accumulation, wherein the malaerated organ produces a persistent opacity to x-ray that is obviously unreducible by aspiration. Large extracostal or intrapulmonary hematomas, lobular or lobar atelectasis due to bronchial obstruction, bronchopneumonia, are usually easily distinguishable from the aforementioned condition and need not be discussed.

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For purpose of clarity these topics will be reviewed, proceeding from the more simple to the more complex.

Simple Hemothorax.—By this term is meant the presence of blood in the pleura unaccompanied by complicating features. The natural history of this situation, however, deserves mention. Omitting any discussion of chest wall, pulmonary, or other chest injuries incurred at the time the hemothorax is produced, certain changes are known to follow, as a result of repeated observation. Blood is a known pleural irritant and as a result of this a response by the pleura can be expected. This response takes the form of an effusion which, in its basic state, is conceded to be serous in character. After an initial intrapleural hemorrhage, increases in the amount of pleural fluid are not necessarily indicative of added bleeding. Frequently, the first thoracentesis after wounding yields fluid that is distinctly bloody, and, when thoracentesis is serially repeated, the character of the fluid changes to serosanguineous and finally serous before it ceases to be present. Pleural fluid from cases of reducible hemothorax has been found to be low in protein and relatively low in red blood cells.

Even in these cases there is a certain amount of fibrin deposited over the pleural surfaces to form a thin, shaggy, pleural coat, but it is insufficient to prevent aspiration and is not recognizable by x-ray.

Infection developing in a simple hemothorax follows in general the course of a suppurative pleuritis and offers no difficulty in management. In uninfected patients a moderate febrile response may be seen, but this is of short duration.

Organizing Hemothorax.—The principal feature to be noted on gross inspection is, of course, that the intrapleural mass is more or less solid, which solidity is due to a spongy mass of fibrin. The distribution of the mass follows the same general pattern adopted by liquid pleural accumulations in recumbent subjects, since it is thickest in the basal thoracic gutter posteriorly, thinning from there both anteriorly and toward the apex superiorly.

The intrapleural mass reveals in the idealized case three layers (see Fig. 1). The first of these is a tough coat or "peel" closely applied to the pleural surfaces, both visceral and parietal. The second is a layer of unorganized fibrin of varying thickness, central to this. The third is represented by a cavity filled with fluid, typically loculated, and occupying the center of the fibrin mass.

The outer layer is a tough, organized membrane, intimately but separately applied to the pleural surfaces and completely surrounding the intrapleural mass. It varies in thickness with the age of the process, which time is most conveniently measured in days from day of wounding. By four to five weeks this layer may reach 2 to 4 mm. in thickness and is by this time a resistant layer which does not tear easily, having the gross appearance of fibrous tissue. It usually passes directly from visceral to parietal pleura at all points where these surfaces meet, although attenuated projections frequently extend beyond these limits into the interlobar fissure or along between opposed pleural surfaces. The costophrenic gutter is consistently obliterated by an elevated diaphragm and is sealed off by the reflection of this peel. Beyond these points of pleural symphy-

sis one may be quite surprised to find only a thin layer of filmy pleural adhesions, or, at some distance away, an entirely free pleural space.

The next layer is a soft, unorganized mass, having the consistency of fibrin. It varies grossly in appearance from case to case, but this difference is chiefly in respect to color. In some instances it may be almost typical of "white clot," whereas in others it may be mahogany colored or distinctly bloody. This would appear to depend on the relative proportion of blood and plasma or pleura effusion or pleural exudate originally accumulated, modified by whatever degenerative changes may have occurred in aging. Although the appearance of this layer is usually fairly uniform, a certain degree of "marbling" is not uncommon.

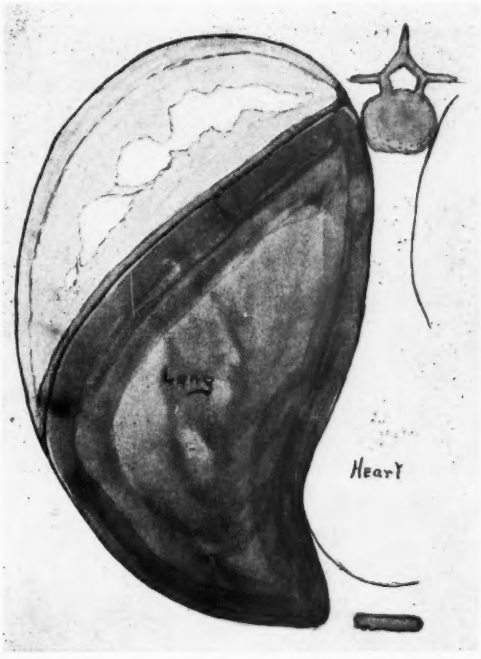

Fig. 1.—Diagrammatic cross section of hemithorax in organizing hemothorax, costal chest wall not represented. The pleura is represented by the heavy black line, the parietal leaf encompassing the intrapleural mass posteriorly, the visceral leaf surrounding the lung. Symphysis of the pleural layers occurs at the border of the intrapleural mass.

The actual center of the intrapleural mass is occupied by fluid. The central space is typically loculated and may range from merely a mushy core from whose interstices fluid can be squeezed, to a definite network of fluid-filled spaces or even one large, single space. The appearance of this fluid is exactly what one would expect the supernatant fluid from the main retracting fibrin mass to be, and, therefore, varies from yellow to red, brown, or mahogany in color. This central, fluid-filled space is undoubtedly created by retraction of the clot.

In this description of the gross appearance of the intrapleural mass in organizing hemothorax, emphasis has been placed on the variants so frequently noted. The term organizing hemothorax in its strict sense does not describe such variants because one would expect the intrapleural mass to be the result of clotted whole blood. Experience indicates that the gamut is run from cases where the intrapleural mass is whole blood through cases where a considerable proportion of blood is present, but increments of white clot (that is, plasma, fibrinous pleural effusion, or exudate) have been added, as suggested by a marbled appearance, on to cases where the entire mass is virtually a white clot. Thus, in the established case, the amount of whole blood originally spilled into the pleura is not necessarily as important as the subsequent pleural response may be.

Fig. 2.—Infected organizing hemothorax. Section through organizing layer of clotted hemothorax. The upper half of the field is near the pleural surface and consequently is older. The leucocytic infiltration is apparent in the younger portion, and the rather sharp line of demarcation is striking in this instance.

Histologic examination of these various layers confirms what has been implied above (Figs. 2 and 3). In the tough layer adjacent to the pleura there is organization of the fibrin mass. This is indicated by invasion of endothelial buds forming capillary networks containing blood. Fibroblasts and their intercellular deposits are present. The depth to which this process has gone is directly dependent upon the age of the clot, but for some reason is usually thicker on the parietal pleura. It can be seen to be well advanced by one week's time after wounding, and there is no reason to believe that this organization differs in any way from the better-known process of organization in intravascular thrombi. The second layer is merely a mass of fibrin with scattered formed blood elements trapped in its meshes.

The pathogenesis of organizing hemothorax is not entirely clear. Facilities for experimental investigation of the causes for clotting in some cases of trau-

matic hemothorax and not in others have hardly existed. Considering the problem in light of factual observations, however, permits reasonable speculation.

A review of cases has been undertaken with the hope of finding some common factor which might reasonably explain the phenomenon. Those factors considered most likely include the type of missile, the degree of pneumothorax incurred, the severity of lung or soft tissue wounds. Such researches were definitely disappointing since no true parallels could be drawn and we are thrown back to searching the mechanism of clotting for an explanation. With this in mind, three possible explanations present themselves for consideration: (1) that clotting is the result of the presence of blood and coagulative ferments simultaneously in the pleura; (2) that a modification of the pleural fluid, which occurs as a result of wounding, causes this fluid to be exudative rather than serous; (3) that bacteria, by their presence in the pleura, may incite an exudative rather than a transudative type of response.

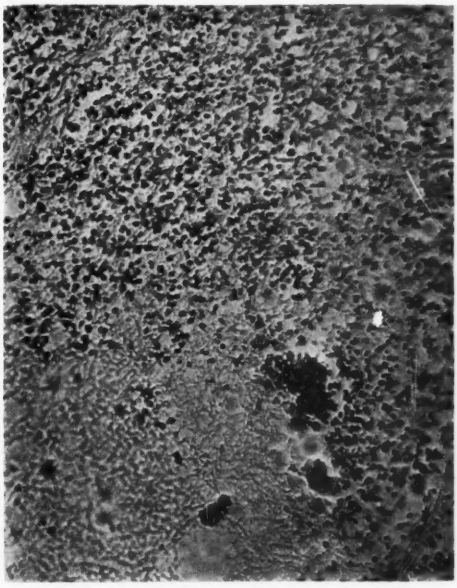

Fig. 3.—Infected organizing hemothorax. Section through periphery of unorganized fibrin. Leucocytic reaction is dense, but again a rather sharp line of demarcation is apparent at the deepest line of leucocytic penetration, despite the presence of a colony of bacteria in the field. Such a focal point will soon become an abscess.

The first hypothesis is not entirely satisfactory because, as has already been pointed out, the amount of blood actually present does not seem to be important since there is often a great preponderance of white clot, indicating considerable excess of plasma in some instances. It is true that clotted blood has been found in the pleura at thoracotomy within four to six hours after wounding, that a satisfactory explanation for the old contention that intrapleural blood remains liquid has never been given, and that both the lung and muscle are ready sources of thromboplastin, yet this simple proposition fails to explain adequately the

vagaries seen clinically. Thus, returning to our opening statements, it would seem to be true that in some instances the presence of whole blood and coagulative ferment may result in a true organizing hemothorax, yet many more cases are left unexplained because there has obviously been more than just blood spilled into the pleura.

The second hypothesis seems much more reasonable. As was seen under the discussion of simple hemothorax, a response by the pleura is expected as a result of blood spilled into the pleura or as a result of wounding or both. Wounds of the lung, or for that matter the pleura, cannot be fundamentally different from wounds of other tissues, and are, no doubt, like them, subject to the "edema of wounding," which can be expected to reach a peak at two to four days. Such an occurrence would undoubtedly affect the character of the pleural effusion and would in all probability render it richer in fibrin. Under such circumstances one can easily accept the presence of an excess of coagulative ferment (if its presence be necessary for clotting to occur) from the wounded lung or chest wall, and also the presence of an effusion, enriched in fibrin, appearing in the first few days. Thus, there would be a certain amount of whole blood spilled into the pleura which may clot and to which there will be added the increments resuling from the pleural response. It has been previously shown[1] that evacuation of pleural clot at early thoracotomy does not insure against the development of a subsequent clotted intrapleural mass. This can be understood when it is realized that wounds of the lung result in rather widespread change referred to as the syndrome of the "wet lung."[2] Such lungs are soggy, heavy, and sluggish in expanding, so that the persistence for a few days after wounding of a pleural space by virtue of an incompletely expanded lung would permit the accumulation of pleural exudate, as referred to above, and, therefore, could easily lead to the development of a clotted intrapleural mass. If all of the blood in the pleura were removed at the primary thoracotomy and pleural exudate were allowed to accumulate thereafter, the intrapleural mass would in all probability be largely "white" in appearance. If all the blood were not removed, it would then be layered or marbled. Under this hypothesis, therefore, an explanation is given of the clinical vagaries and also of the relationship of the occurrence of this process as a sequel to rather severe original wounding.

It seems further acceptable that once the necessary reagents are present together in the pleura, clotting should proceed to the exhaustion of one or more of the reacting agents. Experience indicates that if clotting is to occur, it can usually be detected by three to five days postwounding, and if it is not to occur in significant degree, the pleural fluid will be liquid up to two or three weeks or longer and occasionally the pleura may be rendered dry by even a single thoracentesis at this late date. Admittedly, there are those cases in which numerous small clots are present in an otherwise thick and viscid but liquid blood, so that all degrees of clotting may be encountered, suggesting that the quantitative proportion of reacting substances determines the extent of clotting.

The third hypothesis becomes somewhat more involved, but it is believed that bacteria are frequently present in organizing hemothorax, if not constantly

so. As in the second hypothesis, their presence would be expected to produce an exudative response by the pleura which would favor formation of fibrin deposits. If bacteria were to be seeded generously, they would, no doubt, be implanted along the pleural surface and a frank, suppurative response would be expected, resulting in a true suppurative pleuritis. If, however, the organisms are implanted in small numbers so as not to produce a widespread pleural response, their presence may be sufficient to alter the character of this response toward an exudate rather than a transudate, whereupon fibrin deposition may become the dominant clinical picture. Certainly, sharp and prolonged febrile responses are seen in cases of organizing hemothorax. This reaction continues if suppuration is impending, but generally subsides in ten days to two weeks if prompt suppuration is missed.

Infected Organizing Hemothorax.—The diagnosis of established infection in simple as well as organizing hemothorax depends upon the clinical signs of sepsis and toxicity, confirmed by positive bacteriologic findings. In simple hemothorax this generally offers no difficulty, since the pleural content is readily aspirable. In organizing hemothorax, however, the difficulty in aspiration may be such that at some points no fluid will be obtained, although some amount of fluid usually is obtainable.

Certain variants in the clinical response to infection in organizing hemothorax are worthy of mention: (1) Cases are seen with clinical signs of sepsis but with bacteriologically negative fluid. These may represent the cases alluded to in the paragraphs above, wherein bacteria are not present in demonstrable numbers in the center of the mass, or wherein, by unfortuitous circumstance, the needle was not introduced into a loculation which contained them. If such a case is definitely infected, repeated attempts, of course, would be rewarded with positive bacteriologic findings as the infection spreads to involve the mass more extensively or as other sites are selected for puncture. (2) There is also an interesting group of patients with signs of sepsis in whom organisms are found in the aspirated fluid but who exhibit virtually no local leucocytic response, the fluid being thin and practically without sediment, despite great numbers of organisms. (3) Suppuration, as evidenced by the aspiration of pus, may be delayed for four to six weeks in some cases. This poses a very interesting problem both from the standpoint of pathology as well as management.

The factor or factors determining which cases do go on to prompt suppuration and which do not cannot be conclusively designated, but undoubtedly represent the result of a balance between rapidity and extensiveness of the clotting, thereby isolating in the fibrin mass and away from contact with the pleura, the infecting bacteria on the one hand and the ability of the pleura to control or eliminate those bacteria which originally were in contact with it on the other. If the early seeding of bacteria is heavy with virulent organisms, a prompt purulent reaction is produced and a suppurative pleuritis is the fundamental pathologic process. This results in an early involvement of the entire content, liquid or clotting, in a suppurative process. If, however, the contaminating bacteria do not, for whatever reason, soon gain the ascendency,

and do become entrapped within the clotting intrapleural mass, the mechanism of true latency in infection is set up. Focal points of intense reaction are occasionally seen and miliary abscesses may occur in the older portions of organizing clot as a result of some such process, but these layers are usually amazingly free from inflammatory reaction (see Fig. 2). To speak teleologically, the pleura and layers of adjacent organized clot with their blood supply have cleared themselves of the infection. This observation helps explain the good results obtained by decortication even in the face of frank suppuration within the center of the fibrin mass. The cause for delay in total or frank suppuration of the intrapleural mass (indicated by the aspiration of pus) is demonstrable by histologic means.

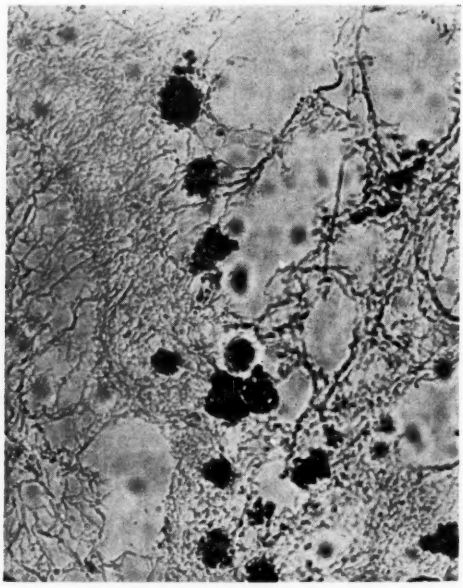

Fig. 4.—Infected organizing hemothorax. Section deep in the unorganized portion of fibrin, illustrating bacteria (hemolytic staphylococcus on culture) growing in masses in its meshes. Leucocytes are conspicuously absent.

The accompanying illustrations (Figs. 2, 3, 4, 5, and 6) are from a patient, running a septic course with fever to 104° F., four weeks after wounding. This soldier had sustained a severe, penetrating wound of the right chest, resulting in an extensive pneumothorax and clotted fibrinothorax, which was chiefly basal. Small amounts of clear fluid supernatant to the clot could be obtained by thoracentesis and on smear were seen to be teeming with bacteria, hemolytic staphylococcus by culture, but exhibited a negligible number of leucocytes. Examination of Fig. 2, taken through the organized portion near the pleura, reveals the relative absence of leucocytic infiltration in the older portions, but moderate infiltration in the more recently organized and organizing layers.

Fig. 3 is from a section taken deeper in the unorganized portion of the intrapleural mass. Here the dense leucocytic infiltration is noted, but the striking feature is that despite the presence, within the field, of bacterial colonies, the leucocytic infiltration stops along a relatively well-demarcated border as if the leucocytes were unable to respond in any significant number to such a strong chemotactic situation.

A section taken still deeper within the fibrin mass (Fig. 4) reveals numerous bacterial colonies unattended by leucocytes. This case, then, represents one of severe clinical sepsis in which an abundance of organisms is present deep in the intrapleural mass, yet in this area there is minimal or no evidence of leucocytic response.

If these sections (Figs. 2, 3, and 4) are placed in their proper sequence, it is readily noticed that the older and organized portions nearest the pleura are free of significant inflammatory reaction, yet deeper in, the leucocytic response is very generous, although it has not reached the central portion of the intrapleural mass. If it is realized that these leucocytes must have a point of departure from a blood vessel, it can be readily seen that the young endothelial buds which participate in the organization of the fibrin mass constitute their closest source. It seems logical to believe and is presumably demonstrated by the rather sharp line demarcating the zone of leucocytic infiltration centrally, that they are able to migrate from their point of departure for a limited distance only through the fibrin, and that they, therefore, can only reach the center of the mass when their point of departure comes within sufficient proximity to this area. This explains, along with the other considerations, why there frequently will be one loculation containing frank pus in an organizing hemothorax. Such a loculation is very often situated in the thinner portion of the intrapleural mass (most often anterolaterally), thereby permitting the accumulation of a sufficient number of leucocytes to be recognized as gross pus on aspiration here, ahead of other, more deeply situated, loculations. It must also be remembered that the aspiration of pus depends upon there being an adequate number of leucocytes accumulated at that point, so that repeated attempts may be made in an obviously septic pleura before such a yield may be had. These illustrations also indicate that the infection is generally confined to the center of the intrapleural mass, tending to spare, if not entirely sparing, the pleura itself.

Suppuration within the pleural mass need not be delayed until such time as the leucocytes can reach through the fibrin barrier all along the borders of the central cavity. Having accomplished this at some point in a thinner portion, they will, no doubt, respond to the potent chemotactic situation with increasing alacrity by pouring through this breach.

Fibrothorax.—Casting aside for the moment the suggestion that infection or bacterial contamination is constant or frequent in organizing hemothorax, the production of a clinical picture consistent with fibrothorax is not difficult to understand. These patients present an over-all contracture of the involved hemithorax, narrowing of the intercostal spaces, elevation and more or less immobility of the corresponding diaphragmatic leaf, often very marked limitation of the

chest wall motion, and associated atrophy of the extracostal musculature from disuse. The x-ray reveals a dense opacity corresponding to the area of the original hemothorax. Resorption and consequent improvement in the x-ray shadow have been seen, but the narrowing of the interspaces, the contracture of the chest wall, and its relative immobility very often remain despite such clearing. The exact extent of an organizing hemothorax, which may spontaneously

Fig. 5.—Infected organizing hemothorax. Extensive hydropneumothorax following penetrating wound.

Fig. 6.—Infected organizing hemothorax. Lateral decubitis film. Extensive hydropneumothorax following penetrating wound. The base is occupied by an opaque mass, thinning toward the upper chest. Vacuolation can be noticed, indicating the basal opacity to the solid. Therefore, it is, in all probability, fibrin. (Same case as Fig. 5.)

clear by x-ray with adequate return of function, is not definitely known, depending no doubt upon the thinness of the intrapleural mass casting the shadow. It is, however, to be remembered that this improvement can be expected only in the thinner portions. The thick areas of the intrapleural mass, notably in the gutter posteriorly, have been demonstrated eight and ten weeks after apparently almost complete roentgenologic clearing had occurred.

The process of organization, if carried to its completion, would result in the presence of a dense fibrous plaque encasing some portion of the lung, preventing its complete expansion, contracting the chest wall, and limiting its mobility. Organization would be carried to the depth of the fibrin coat. If the intrapleural mass were composed of solid fibrin, then the scar tissue plaque

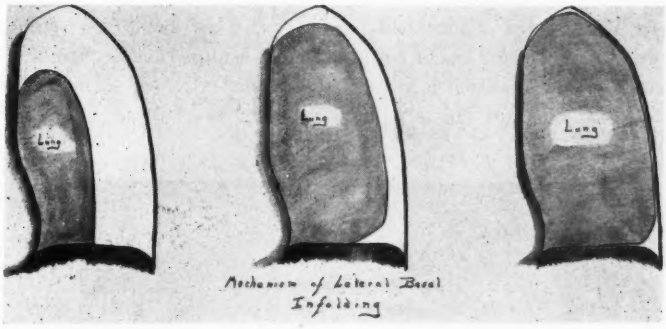

Fig. 7.—Diagrammatic representation of mechanics of simple basal infolding of lung. For clarity, hemo- or hydrothorax is not represented. Initial phase at left.

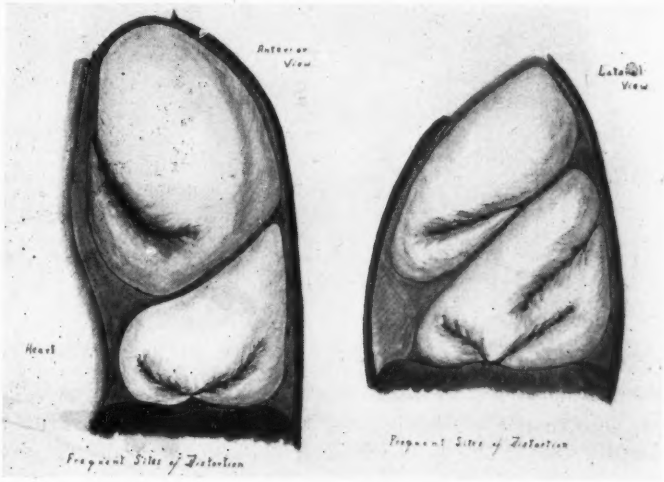

Fig. 8.—Diagrammatic representation of extent and sites of infolding seen at thoracotomy. The lung is poorly tailored to fit the hemithorax under these circumstances and pleural fluid is prone to act as a substitute, contributing to the opacity seen by x-ray.

would be very thick. It is more frequent, however, for the center of the mass to be made up of fluid, and in the old cases that have come under observation, the intrapleural mass is transformed into a fibrous sac containing old blood or serum.

If bacteria are consistently present, as has been suggested, and if frank suppuration does not supervene so that drainage, decortication, or evacuation

of the septic products is accomplished by some means, it seems logical to expect that sterilization of the center of the intrapleural mass cannot consistently occur. True latency may then result and foci of infection deep in the pleural mass may remain. This seems to be a very likely possibility and if so, it can be predicted that patients with fibrothorax or neglected organizing hemothorax will be seen in the postwar period, presenting the persistent x-ray finding that has so erroneously been called "thickened pleura," and subject to recurrent, febrile episodes due to recrudescences of activity in foci of infection or chronic ill health. Even though such a situation is suspected, demonstration of such focal infection will be very difficult and the satisfactory treatment of these patients will be a serious problem.

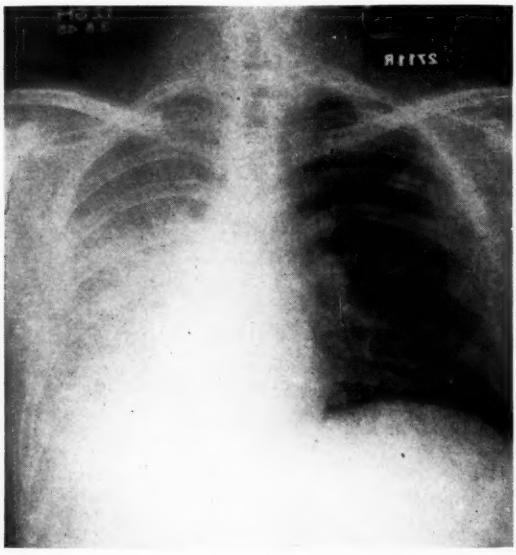

Fig. 94.—Posterior-anterior x-ray projection of typical organizing hemothorax.

Infolded Lung or Deforming Adhesive Pleuritis.—As indicated in the introduction, at least one condition other than an inaspirable hemothorax may follow thoracic trauma and so closely simulate a gross organizing hemothorax that confusion is very likely to occur.

Since the average case of organizing hemothorax is seen at a time when the underlying lung has filled the available portions of the thoracic cavity, the discussion of infolded lung will be begun with a comparable x-ray picture. The points of confusion can be briefly presented. The opacity by x-ray is often quite dense, is typically basal, and cannot be eliminated by thoracentesis. The physical findings are usually dullness to percussion, decreased tactile fremitus, and suppression of breath sounds. There is narrowing of the interspaces. There may be retraction of the mediastinum toward the affected side, with elevation

and relative immobility of the corresponding hemidiaphragm. There is always the history of trauma, and blood has usually been obtained on thoracentesis because this element is present in virtually all wounds of the pleura.

Careful investigation of the evolution of these cases, however, reveals that a pneumothorax was the predominant feature early, with varying amounts of blood added as an inevitable concomitant. Reference to Fig. 7 will illustrate diagrammatically what is believed to occur in the simplest type: As a result of the wound and consequent pneumothorax, the lung is deflated, and the diaphragm is elevated and splinted. The only unique feature of the process is that apparently the costophrenic fringe is retracted, being dragged along the dome of the diaphragm. In all probability, because of the blood which is present, pleural symphysis occurs at the "tide-water mark" between the visceral coat

Fig. 9*B*.—Lateral x-ray projection of the same case as in Fig. 9*A* showing typical localization of major destiny in the posterior chest.

of the costophrenic fringe and the diaphragmatic pleura. As a result of absorption of the air or aspiration of blood and/or air, the lung begins its process of re-expansion by rolling out over this area of pleural symphysis which remains fixed. The upper portions of the lung are, of course, free to expand and fill the apex, whereas the peripheral portion of the base of the chest must be filled by lung adapting itself to this space. It is, of course, then seen that an area in the periphery of the base has no free lung to readily fill it, and pleural fluid is prone to act as a substitute. This is the simplest form of this condition and obviously is of no great clinical significance.

Very extensive degrees of infolding and distortion of the lung by symphyses between visceral and parietal pleurae or, even more striking, symphyses between

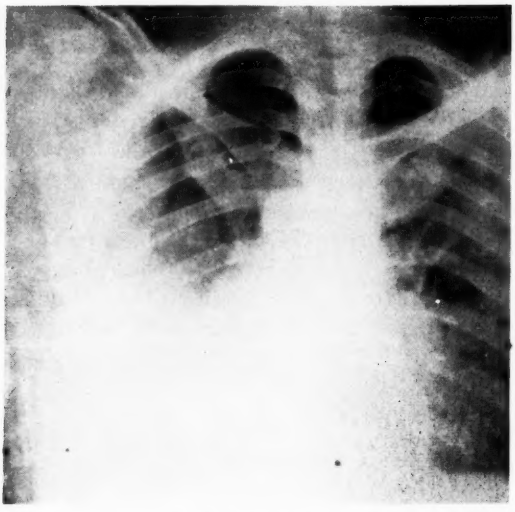

Fig. 10*A*.—Infolded lung. Frontal x-ray projection of a case of traumatic pneumothorax shortly after wounding (Perforating bullet wound, left chest). The lung is incompletely expanded. Subcutaneous emphysema is still demonstrable. The basal opacity at this stage is probably due to several causes, including pulmonary hemorrhage, intrapleural blood, and/or fluid, even possibly retained bronchial secretions.

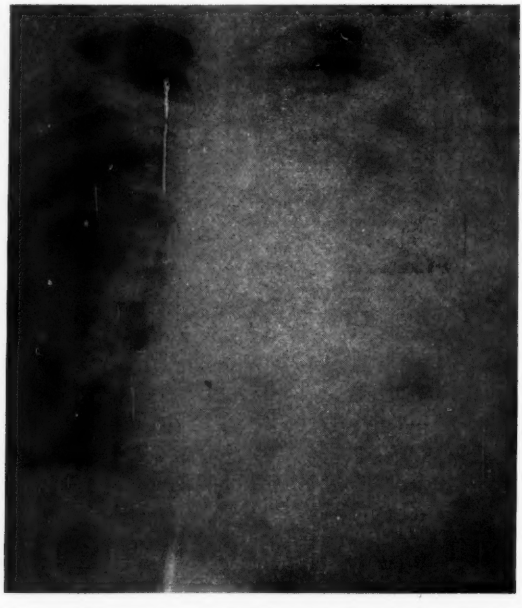

Fig. 10*B*.—Infolded lung. Same case as Fig. 10*A*. Shows extensive opacity of the lung field. Small amounts of serous fluid could be obtained by aspiration.

opposed portions of visceral pleura are seen (Fig. 8). The exact mechanism whereby these bizarre distortions are produced is not at all clear, yet they have been encountered, including even a symphysis between the lateral costophrenic fringe and the mediastinum along its diaphragmatic border. In these more complicated situations the hemithorax is, of course, filled more reluctantly and more incompletely, so that areas within the thorax that are not adequately filled by portions of lung are prone to be filled by recurrent accumulations of pleural fluid. Thus, fluid may be obtained by thoracentesis in small amounts in this condition, but is prone to recur and is uniformly serous in character after the blood originally present has been removed. Because of the opacity produced by

Fig. 10*C*.—Infolded lung. Same case as in Figs. 10*A*, and 10*B*, revealing ill-defined nature of lesion in this view in contradistinction to organizing hemothorax (see Fig. 9*B*).

the infolded and malacerated areas within the lung, plus the opacity resulting from irregular and usually intercommunicating small collections of pleural fluid, confusion with the x-ray picture of organizing hemothorax is easy to understand. Thus, if this process involves large areas of the lung, expansion may be considerably slower and filling of the hemithorax considerably delayed. This fact, of course, explains the contracture of the chest wall, which is merely an attempt to reduce the size of the pneumothorax.

In its pure form, an infolded lung may be distinguished from organizing hemothorax not only by the early predominance of pneumothorax or the presence

of recurring small amounts of serous fluid, but more accurately by the lateral x-ray. In organizing hemothorax the opacity on the x-ray film is posterior and basal, whereas in cases of infolded lung the obscuration is patchy and diffuse, there being no localization of the process in this regard (Figs. 9*A*, 9*B*, 10*A*, 10*B*, and 10*C*).

When a hemothorax is produced, as a result of pleural penetration, there is also in all probability a certain amount of concomitant pneumothorax, whether this is demonstrable or not. If the blood is the predominant intrapleural feature and it goes on to clotting and organization, the typical picture of organizing hemothorax is seen. However, when the intrapleural mass in organizing hemothorax is removed, as by decortication, it is easy to recognize the fact that the lung has not only been compressed by this amount of pleural accumulation but has also very frequently been displaced so that infolding of the lung is a very frequent finding under an organizing hemothorax. One has the impression that a rather large accumulation of blood was present in the pleura, the lung was further compressed by a certain amount of pneumothorax, the pleural blood clotted, and the lung filled the rest of the available pleural space by expanding those portions of its contour which could most easily do this.

After completion of a decortication the pleura may appear grossly normal and it will be only the recognition of an abnormally blunt lateral fringe of lung, an unusually short lingula, or a relatively small-sized lower lobe that warns the surgeon to search for areas of infolding. It is, therefore, paramount in decortication that the lung be freed from its points of symphysis along the parietal or diaphragmatic pleura so that these abnormalities may be recognized. The points of attachment between the visceral and parietal surface, for example, at the costophrenic fringe in an extensive basal distortion, may not permit unfolding of the involved fringe, if freed because there may be a symphysis between the opposed diaphragmatic surfaces of the visceral pleura. This attachment of one visceral surface to another is usually much less firm than that between the visceral and parietal portions, and the operator's finger may be slipped in this groove to discover an interpleural tunnel covered over by a veil of thin adhesions. Freeing this veil will permit unfolding and resumption of normal contour by this portion of lung.

The careful and complete lysis of deforming adhesions after decortication of an organizing hemothorax is imperative to insure prompt and complete lung reexpansion, which is the best possible insurance against a complicating empyema, to say nothing of having left the patient with a situation only slightly more favorable than the one eradicated (Fig. 11).

The importance of distinguishing a severely infolded lung from an organizing hemothorax resides in the belief that the latter constitutes a definite indication for a thoracotomy and decortication, respecting, of course, the necessary criteria for severity, whereas the former may not. Although experience with the pure form of infolded lung is confined to some four cases, certain guiding criteria may be laid down concerning the possibility of surgical correction.

If the infolded lung has expanded sufficiently to fill the hemithorax, even though this be contracted three to four weeks after wounding, it is believed that return of function in the chest wall by the practice of breathing exercises will permit eventual correction of the condition and a satisfactory end result may be expected. This is particularly true if it can be seen, on serial x-rays, that this pulmonary expansion has been proportionately shared by all lobes so that, for example, the patient is not left with an over-expanded upper lobe and a severely contracted lower lobe. If, however, the lung has not succeeded in filling the hemithorax in three to four weeks, or if, on the basis of serial x-rays, it can be detected that the filling of the hemithorax has been accomplished predominantly by one portion of the lung, release of the limiting adhesions is probably justified. Under the circumstances, where filling of the hemithorax is long delayed, however, it is quite more probable that the failure to expand is not so much due to the infolding as it is due to the presence of a definite retaining peel of organizing hemothorax, in which case decortication is definitely indicated.

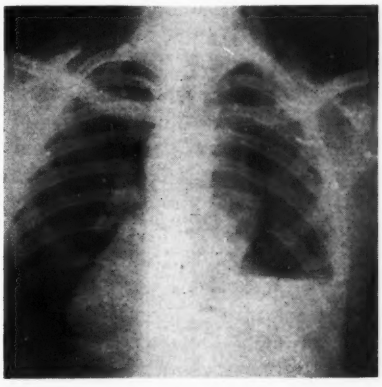

Fig. 11.—Infolded lung after decortication in which extensive deforming adhesions were not recognized and freed. Lung required six weeks to fill the hemithorax. Infection did not supervene.

Thus, organizing hemothorax and infolded lung are believed to be pathogenetically related and some degree of infolding is constantly seen under a massive intrapleural clot.

If pneumothorax is the predominant result of wounding, and the extent of clotting in whatever blood or pleural fluid may be present is minimal, a very thin peel is laid down, represented by retaining veils of pleural adhesions. Here again the points of contact with the parietal pleura are the densest. If the hemothorax is of moderate size and clotting is more extensive but still subtotal and the lung suffers a major degree of collapse as a result of the wounding, a moderately thick peel may be found encasing the lung and greatly delaying, if not effectively preventing, its expansion.

Finally, we recognize the typical picture of gross organizing hemothorax, in which case distortion of the lung assumes a secondary role, being of importance only as an obstacle to prompt postdecortication expansion.

SUMMARY

Even though final elucidation of the pathogenesis of organizing hemothorax may not be at hand, it seems clear that the deposition of fibrin in the pleura is the fundamental pathologic process and accounts for the vagaries seen clinically.

The pleura responds to trauma or blood. This response takes the form of an effusion which is basically serous in character. Alteration of this response by the severity or type of the trauma, or by contaminating bacteria is suggested as the source of excesses of fibrin. If coagulative ferments are required to produce fibrin deposition or clotting, the wounded lung or chest wall offers adequate sources.

Unattended, a clotted hemothorax or fibrinothorax becomes a fibrothorax by organization of the intrapleural mass in a manner similar to that seen in intravascular thrombi or suppurates.

The odd clinical behavior of the infected patients is explainable by the presence of fibrin acting as a barrier interposed between the main body of infecting organisms and the pleura. Leucocytes are apparently limited as to the distance they can infiltrate into a fibrin mass from their point of departure. Thus, a delay is required before they can accumulate in sufficient numbers in the center of the pleural mass to be aspirable as pus.

Finally, a clinical picture confusable with, but distinguishable from, gross organizing hemothorax, due to severe distortion and infolding of the lung, is described. Since this condition is believed to be pathogenetically related to organizing hemothorax, it constitutes another cause for chronic hemothorax as defined.

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(*See discussion on page* 146.)

THE TREATMENT OF ORGANIZING HEMOTHORAX BY PULMONARY DECORTICATION

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HEMOTHORAX is the most common complication of intrathoracic wounding. However, throughout the years which have separated the two world wars it has attracted only occasional thought and comment in medical literature. Those who considered its treatment have been divided into two schools—those who thought the presence of the blood detrimental to the welfare of the patient and advocated its early removal, and others who felt that absorption of the sanguineous intrapleural material would soon and invariably take place. Elkin[1,2] stated that in 95 per cent of all instances of hemothorax the blood was absorbed. When the literature is searched, one is impressed with the fact that only a few investigators have concerned themselves with the fate of the 5 to 10 per cent of individuals with hemothorax who, as a result of its presence, developed empyemas which became chronic, a contracted hemithorax, or an encased lung with its resultant crippling of respiratory function.

Smithy,[3] during the year 1942, appears to have been among the first, at least in this country, to suggest that all hemothoraces did not heal spontaneously and that the percentage of complications which became bothersome to the host was much higher than was ordinarily supposed. In an illuminating article he presented three patients whose troubles, arising from an inaspirable hemothorax, set the pattern for those cases soon to be seen in wounded soldiers.

It was in such a state of ignorance that most thoracic surgeons faced this problem when the war was new. As far as is known, the numerous writers on the treatment of chest wounds prior to the year 1943 mentioned only the fact that blood might clot in the pleural cavity, but made no suggestions as to the treatment of such a complication should it arise.

Thus the problem of the clotted hemothorax in the early months of our engagement in combat became a confounding one. The soldiers thus affected were very ill, sepsis was often extreme, and because blood replacement was still not well established due to inadequate supplies, the subsequent morbidity was great. It was only when the large, clotted mass had finally become completely liquified by suppuration that the acute process could be terminated by a thoracostomy with drainage of the empyema. In those instances where suppuration did not occur and the clotted mass finally organized, the patient was left with a contracted hemithorax which not only encased the lung and vastly reduced its function but also caused marked deformity of the thorax on the affected side in some individuals. From the experience gained in World War I,

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where the treatment of wounded thorax was not unlike that carried out by us early in World War II, the incidence of chronic empyemas was high. It must of necessity follow that a similar high incidence of chronic empyema was seen in those individuals who received their thoracic wounds during the months when the war was still young.

As far as we are able to determine, decortication of the lung in the treatment of organizing hemothorax was first used during 1943 in the Mediterranean Theater of Operations by Major Thomas Burford. The procedure itself was not new, having been suggested and used by Fowler[4] in 1893 in the treatment of chronic empyemas, it being correctly reasoned that the failure of the lungs to reexpand was in the main due to its encasement by an inexpandable fibrous peel which covered and in some instances became part of the visceral pleura. A year later Delorme[5] employed this operative procedure in a manner similar to Fowler. During the early years of this century and until some years after World War I, the procedure was still used. Finally, because the operation carried with it a high fatality rate which its end results did not appear to justify, it gradually fell into disuse.

Decortication of the lung as employed by our medical corps in World War II in the treatment of organizing and infected organizing hemothoraces gave good results. It allowed the unhampered lung to expand and fill the pleural space. It made it possible for the lung to return rapidly to normal topical anatomy and function in some instances in which hemiatrophy of the thorax was advanced. Where the hemothorax was infected, its use lessened the likelihood of chronic empyema.

This presentation is the result of work done in a general hospital which acted as a thoracic surgery center from late in the year 1943 until the termination of the European portion of the war in the spring of 1945. During this period, 160 decortications of the lung were done in the treatment of organizing hemothoraces and its sequelae. One hundred forty of these patients comprise the basis of this study, the remaining 20 are not included since their ultimate outcome is unknown because of the necessity to evacuate the hospital.

INCIDENCE

The incidence of intrapleural clotting is much higher in war wounds than in the wounds of civil life. Whereas it probably may be placed safely at from 5 to 10 per cent in the latter group, it undoubtedly approaches 15 to 20 per cent in the former group. This will, of course, vary with the severity of the wounds seen. Whereas this group[6] has previously reported approximately 30 per cent of its hemothoraces clotted when first seen during the Italian campaign, the incidence became much lower during the Southern France campaign where the degree of injury in the patients seen was less severe, due primarily to the hospital's location.

ORGANIZING HEMOTHORAX

In some instances the entire pleural space is filled with a solid, clotted mass, while in others the intrapleural mass is a loculated affair composed of areas of clot surrounded in part by locules of clear fluid as well as pools of dark

brownish fluid composed in the main of laked blood. Fibroblasts grow into the mass from both the visceral and the parietal pleurae. Regardless of the nature or type of intrapleural mass, the visceral pleura becomes covered at first with a fibrinous peel, which, as time passes, becomes fibrous in character. It is this peel or membrane which impedes pulmonary expansion even when the intrapleural mass has been cleared. As organization progresses, the lung is bound down more firmly.

From bacteriologic studies of the peel removed at operation we came to believe that bacteria were present in over 90 per cent of the patients treated for organizing hemothorax. This probably accounts for the higher incidence of empyema in the older cases. We have declared infected only those patients in which there was gross evidence of infection.

It was not uncommon in these individuals to find at operation certain loculations within the intrapleural mass which were uninfected, while near these areas there would be a pocket containing purulent material varying in amount from a few to several hundred cubic centimeters. As time progressed these smaller infected areas became larger until the whole mass was involved. Undoubtedly in some instances the fibrous pel sloughed away as a result of the intrapleural suppuration, and expansion of the lung occurred. However, in others this did not take place, and despite pleural drainage the lung remained encased and unexpansible, and a chronic empyema resulted.

OPERATIVE PROCEDURE

The operative procedure consisted in incising through the peel until the visceral pleura was reached. When this plane had been established it was possible by blunt dissection, using small bronchoscopic sponges attached to a long hemastatic forceps, to separate the peel from the visceral pleura. The dissection was carried in all directions until the peel was reflected to the surface of the parietal pleura. We did not feel it necessary to carry the decortication to this pleural surface. However, it is most necessary to free that portion of the lung which, while not encased, is, nevertheless, mildly adherent to the chest wall beneath the reflection and which has become adherent to the diaphragm and the mediastinum. By so doing the lung lobes become free and expansible and the pleural space will be entirely filled. At times it is necessary to arrange the lobes so that they occupy their normal positions. We have found that failure to follow these points often ended in an unsatisfactory result.

Following completion of the operative procedure the chest was drained by two tubes, one placed high anteriorly and the other low and posteriorly in the chest. These were connected to water seal drainage bottles. When expansion of the lung was complete as revealed by x-ray films, the tubes were removed. This was generally possible on the second to fifth postoperative day.

RESULTS

The series presented consists of eighty-nine patients in whom the hemothorax was organized but not grossly infected and fifty-one patients in whom a grossly infected mass was known to be present preoperatively or was encountered at the time of operation.

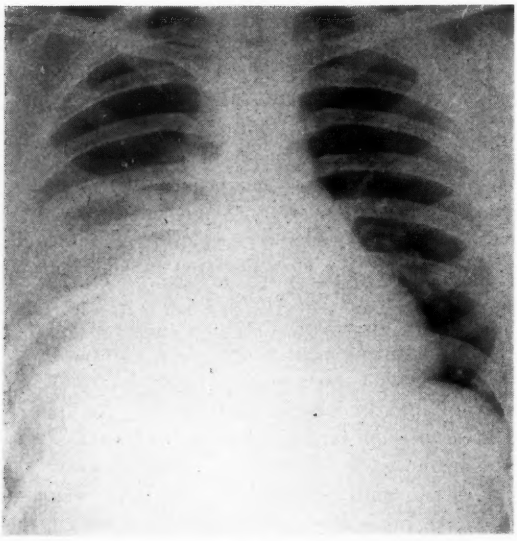

Fig. 1.—D. H. This patient had an organizing hemothorax of one month's duration. It had been impossible to aspirate blood from the chest.

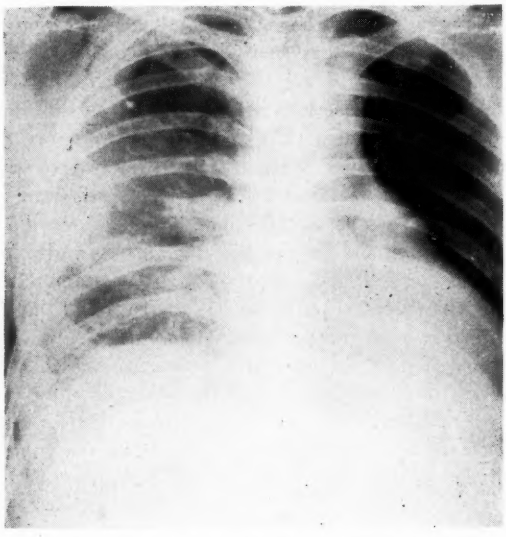

Fig. 2.—D. H. This film of chest was made twenty-four hours after the right lung had been decorticated. The right chest at this time has cleared rather markedly.

It may be seen by referring to Table I that the results were good in 108 instances, or 77.1 per cent; in twenty-six patients the results were considered fair; and in six patients, or 4.3 per cent, a poor result was accepted. The criterion for a good result was essentially that the lung following the operative procedure was expanded completely in 48 hours and the tubes were ready for removal. This criterion was used for both the infected and uninfected cases. A fair result rating was used in those patients where the immediate result was not the best to be hoped for but where the ultimate result was good. Those results not in keeping with either of the above were classified as poor.

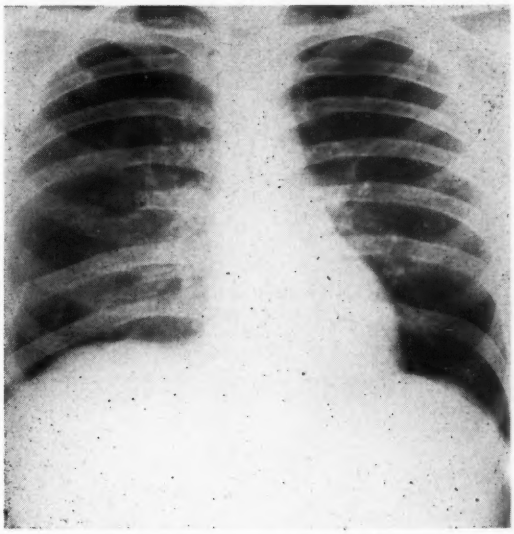

Fig. 3.—D. H. Film of chest made one month after the right lung had been decorticated. The chest is now almost normal in appearance. Soon after this film was made the soldier returned to duty.

It will again be seen in Table I that six patients returned to full duty, 64 to limited service within the Theatre, while 44 were returned to the Zone of the Interior because of the severity of their thoracic wounds. In twenty-three instances the status of the thoracic wound was such that the patient might have returned to duty, but other wounds made this impossible. In three instances the duty status could not be determined from our records.

TABLE I. RESULTS IN 140 PATIENTS FOLLOWING DECORTICATION OF LUNG

RESULTS	NUMBER	PER CENT	DISPOSITION	NUMBER	PER CENT
Good	108	77.1	Duty	6	4.3
Fair	26	18.6	Limited duty	64	45.7
Poor	6	4.3	Zone of interior, chest	44	31.4
Dead	0	0	Zone of interior, other causes	23	16.4
Total	140	100	Duty status unknown	3	2.2

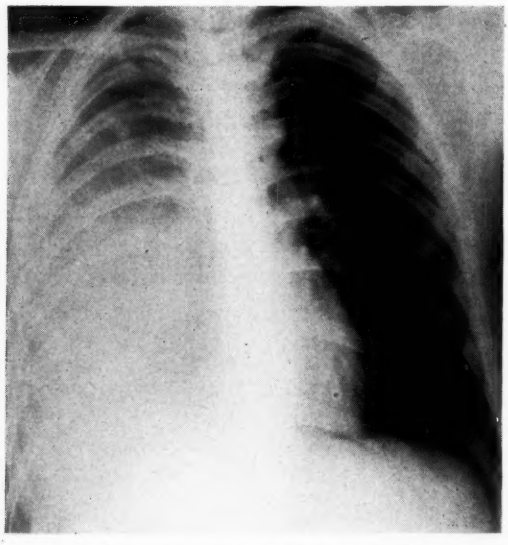

Fig. 4.—R. B. Film of chest of a soldier who had received a penetrating wound of the chest approximately eight weeks previously. At operation it was discovered that the organizing hemothorax was infected.

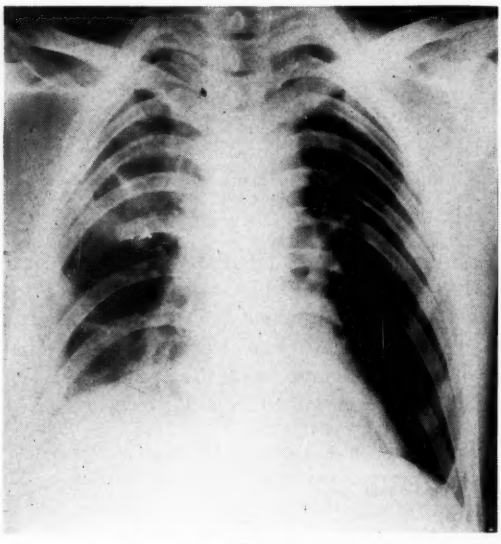

Fig. 5.—R. B. This film of the chest was made twenty-four hours after the right lung had been decorticated.

There were fifty-one patients in which an empyema was present and on whom decortication was carried out. Twenty-five of these experienced primary healing of their empyemas following the operative procedure. By primary healing is meant complete expansion of the lung within 24 to 96 hours, so that the tubes could be removed within a period of seven days. Of the remaining twenty-six in this group, twenty-three had small residual empyemas of from 30 to 200 c.c., which healed completely in a period of weeks or were expanding in a satisfactory manner and in which complete healing could be expected. Three patients had chronic empyemas which would undoubtedly require further surgery.

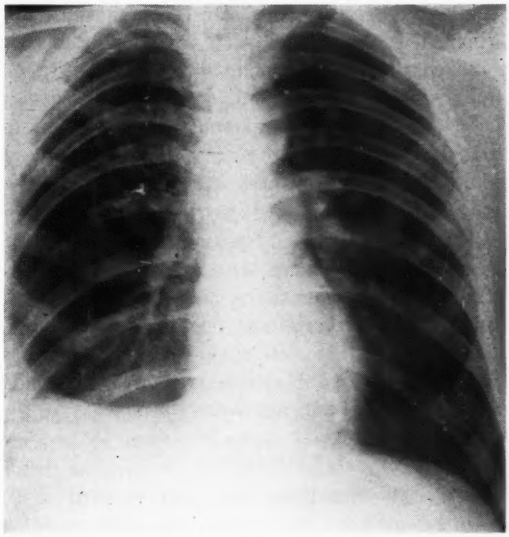

Fig. 6.—R. B. Film of the chest made six weeks after the decortication of an infected organizing hemothorax. Soon after this film the soldier returned to limited duty within the theater.

Among the eighty-nine patients with uninfected organizing hemothoraces there were eight who, subsequent to decortication, developed an empyema and required drainage. Most of these were small pockets and all were healed or progressing satisfactorily on discharge. In none of this group did it appear that further surgery would become necessary.

Expansion of the lung to completely fill the hemothorax was complete within the first twenty-four-hour period in the majority of instances. This was determined by x-ray films and cessation of fluctuation in the water-seal drainage

TABLE II. RESULTS OF INFECTED ORGANIZING HEMOTHORAX FOLLOWING DECORTICATION OF LUNG

RESULTS	NUMBER	PER CENT
Primary healing of empyema	25	49.1
Eventual healing	23	45.1
Chronic empyema	3	5.8
Total	51	100

bottles. Thus, in the entire group, expansion was complete in ninety patients within twenty-four hours and in eighteen additional patients within forty-eight hours. The remainder required periods ranging from seventy-two hours to many days for complete expansion. Naturally most of the empyemas fell in this latter group.

Twenty-three patients had intrapulmonary foreign bodies present, and these were removed when the lung had been decorticated. There were no complications from this procedure.

Penicillin was not always available during the entire course of this study. At first it was not available. It was used in seventy-seven patients and in sixty-three it was not thought needed. Of the eight patients who developed empyemas following the decortication of a presumably uninfected organizing hemothorax, five received penicillin during their immediate postoperative course and three did not. On the other hand, of the twenty-five patients who experienced primary closure of their empyema space following decortication, all received penicillin. It would appear, then, that this form of chemotherapy has value. In no instance in the entire series were sulfanomides used.

Postoperative complications were exceedingly rare. There were no deaths in the group of 140 patients reported, and as far as is known there were none in twenty cases not included. There were two instances in which the wound became infected. Both of these patients had severe empyemas caused, as far as we could determine, by Clostridium welchii. In neither instance was the infection severe. This is rather remarkable when it is remembered that in many of these patients infected material traversed the wound for a period of one to three hours while the operation was in progress.

DISCUSSION

There was considerable discussion among those surgeons interested in this problem as to when the optimum time for decortication might be. Early it was thought by Sampson[7] and by Burbank[8] that a period of eight weeks should elapse from the time of wounding until decortication of the lung should be carried out. They argued that many patients with organizing hemothorax cleared their pleural spaces almost completely in this time. They did not answer the fact that as the time after wounding progressed the incidence of infection in hemothoraces increased. By a method of trial we came to the conclusion that three weeks was the optimum time for decortication in the uninfected hemothorax.

This conclusion was based upon certain salient facts; namely, (1) previous to three weeks the peel was usually not tough enough to be satisfactorily removed; (2) by removing the peel early the incidence of extremely contracted hemithoraces was reduced; (3) when the peel was removed early the incidence of generalized empyema was cut down, because generalized pleural infection as a rule was not present in this period of time; (4) the above-mentioned reasons by their very import reduced the period of morbidity.

As has been mentioned above, it has been stated by several (Burbank,[8] Burke, and Jacobs[9]) that most patients with clotted hemothoraces clear their

pleural spaces in time. Exception is taken to this view by these authors. It is doubtful, if a true organizing hemothorax is present, that time will allow its clearing. It seems most likely that those individuals whose chests were obscured early in their hospital stay and who cleared them in a period of weeks by breathing exercises and expectant care did not have an organizing hemothorax but an infolded lung, the infolded portions of which gave roentgenographic obscuring. We have seen numerous examples of this, and it was only when our interpretation of the x-ray picture had become keen enough that we are able to avoid these pitfalls.

Burke and Jacobs state that in 402 individuals with thoracic wounds seen in their installation there were forty-one instances of inaspirable hemothoraces. Of these forty-one patients, eleven came to decortication and thirty cleared with no appreciable pleural residue. One is inclined to believe that these so-called unaspirable hemothoraces were not such at all but represented patients with infolded lungs in which the amount of intrapleural fluid was extremely small. This view is taken because out of 160 individuals in whom a thoracotomy was done because a clot was thought to be present, the diagnosis was confirmed in every instance but one.

Lofstrom and Koch[10] have demonstrated that there is a rather typical x-ray picture in organizing hemothorax. This is demonstrated by a generalized obscuring of the pleural space in the posterior-anterior x-ray projection and by a triangular posterior obscuring in the lateral film. We feel that a diagnosis of organizing hemothorax cannot be made unless the lateral x-ray film reveals this rather typical appearance.

In 90 per cent of the cases reported in this series the intrapleural clot exceeded 1,000 c.c. in volume. It seems inconceivable to think that such a volume of organizing material could be absorbed in a period of five weeks as is the opinion of Burke and Jacobs or in eight weeks as stated by Burbank. It was for these reasons and because we felt that the morbidity was less that the operative procedure was carried out early. We have no reasons to regret this decision.

There can be no question but that uninfected, organizing hemothoraces do in certain instances produce extreme degrees of respiratory crippling. Such cases, however, do not compare with those seen in individuals in whom infection of the hemithorax is present. During the first world war, chronic empyemas were a most common complication of thoracic wounding. During World War II it appeared that such cases were seldom seen in the European Theatre. This must be due in part to the early use of decortication in these patients.

Nicholson and Scadding[11] report fifty-two patients with infected organizing hemothoraces from the African Campaign, with a fatality rate of 10 to 20 per cent. This is to be compared with a similar group (fifty-one patients) in our series in which there was no fatality. Furthermore, it may be seen that only twelve of their patients were known to be well, while in our series twenty-five, or 49.1 per cent, healed primarily following pulmonary decortication. Such comparison is not made in the attitude of depreciating the report of these workers, it is rather presented to reveal the advantages of early and radical

treatment in such patients before sepsis is severe and before a chronic empyema is inevitable. There can be no question but that a procedure which will result in the healing of 49 per cent of empyemas primarily and a remaining 49 per cent within a period of weeks, with a chronic empyema percentage of 5.8 per cent is worth while.

CONCLUSIONS

1. One hundred forty patients with organizing hemothoraces are discussed.

2. There were eighty-nine patients with uninfected organizing hemothoraces and fifty-one patients with infected organizing hemothoraces.

3. In 108 instances, or 77.1 per cent of the series, good results were obtained. In twenty-six patients, or 18.6 per cent, fair results were obtained. In six patients, or 4.3 per cent, poor results were obtained.

4. Eight patients, or approximately 10 per cent of the uninfected hemothoraces, developed postoperative empyemas.

5. Of fifty-one patients with preoperative empyemas, twenty-five, or 49.1 per cent, healed primarily; twenty-three, or 45.1 per cent, healed within a period of weeks; and three or 5.8 per cent became chronic empyemas.

6. There were no deaths.

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(*See discussion on page* 146.)

TOTAL PULMONARY DECORTICATION

Its Evolution and Present Concepts of Indications and Operative Technique

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THE operation now commonly known as decortication was first performed by Fowler[1] on Oct. 7, 1893. In a previously drained empyema of thirty-three months' duration, a mass of cicatricial tissue occupying three-fifths of the right pleural cavity was dissected free from the thoracic wall, diaphragm, pericardium, and lung. The cavity was packed with gauze and the lung expanded in twenty-eight days. To quote Fowler, "The case suggests a method of dealing with some of the instances of old empyema which resist all of the means usually employed for their cure." Apparently this operation was exploratory in nature and the results were somewhat unexpected.

To Delorme[2] must go greater credit for envisioning and rationalizing the operation, although his first case did not come to surgery until Jan. 24, 1894. In May, 1892, he operated on a "tuberculous" abscess of the chest wall which had an intrapleural extension. Two ribs were removed and a thick membrane overlying the parietal pleura as well as the lung was removed. The lung was thus liberated. In 1893[3] he removed at autopsy a leatherlike membrane from the lung in a patient who had had tuberculous pleurisy for six months and who had died following rib resection. The underlying lung was healthy and could be expanded. Both Oulmont[4] and Cornil[5] had noted previously that the lung beneath the thickened membrane in chronic empyema frequently was normal and that expansion was prevented not so often by pulmonary disease as by the false membrane deposited on the pleural surface. It remained for Delorme to attack this "shell" surgically.

In reviewing the original articles of Delorme and Fowler one is struck by two facts. The word "decortication" was not used by either author. In so far as can be discovered, the term was first applied by Delorme in 1896.[6] Secondly, no mention was made of removing thickened pleura. Rather, Delorme described the pathology as a shell or false membrane encapsulating the lung. There was developed very soon, however, the erroneous idea that thickened pleura was removed, and this incorrect conception of the basic pathology has persisted with few exceptions until the present time. Violet[7] in 1904 fully described the removal of "thickened pleura" and Lund,[8] Lloyd,[9] Hedblom,[10] Smithy,[11] and others[26] gave impetus to the concept in their writings. Similar descriptions persist in several textbooks of surgery.[12] The term "pleurectomy" was employed by Mayo[13] and by Newton.[14] Dowd,[15] however, stated that the firm exudate became

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so incorporated with the pleura that it seemed like thickened pleura. Correct interpretations of the pathology have been made by Lilienthal,[16] Graham,[17] Turner,[18] Moynihan,[19] Battle,[20] and Spencer.[21]

It is of interest to review the essentials of operative technique as originally described by Delorme.[2] A three-sided upper anterior incision was made with the base superiorly in the axillary line. The chest was opened by removing segments of the third through the sixth rib. A thick, fibrous, nonvascular membrane covered both visceral and parietal pleura. The membrane was covered by a layer of "fungosities" which was removed by curettage and sponging. A linear incision was made through the internal wall of the pocket in the region of the collapsed middle lobe and the false membrane was peeled away layer by layer with scissors. At a depth of one centimeter a normally expansile lung appeared, which, following a light cough, herniated through the opening. The lobes and interlobar fissures were liberated and the membrane excised at the edge of the freed lung. The pleural cavity was almost immediately filled with the expanded lung. The membrane on the parietal pleura was not removed. The thoracic wall was closed and a short, large drain was placed in the old sinus.

Modifications of this basic operation were frequent, indicating that results were not uniformly successful. Several individuals combined partial decortication with collapsing parietal operations of the Estlander type,[22] or of the Schede type.[23] Garré[24] incised the shell overlying the lung, then sutured its edges to the parietal pleura as close as possible to the thoracotomy incision. Souligoux[25] incised adhesions at the reflection of the constricting membrane onto the parietal pleura, thus liberating the lung at the edges only. Apparently a similar operation was employed by Lloyd.[9] Ransohoff[26] introduced diseission to promote pulmonary re-expansion. In his group of old and refractory empyemas, Keller[27] found surgical decortication of little value, but obliterated chronic cavities in multistaged operations combining chemical decortication, unroofing procedures, and pedicled muscle transplants. Dowd[15] combined decortication with thoracoplasty.

Many surgeons were concerned with preserving as much of the bony thoracic wall as possible. Roux[28] retracted ribs by an incision in the intercostal space anteroinferiorly. Lloyd stated that in children particularly only one rib need be removed. Lilienthal[29] used a long intercostal incision and rib spreaders both with and without sectioning ribs.

Apparently most surgeons used open drainage following operation,[2, 10, 15, 16] and depended on such things as expiratory exercises and blow bottles to aid in pulmonary re-expansion. Specific reference to the use of intercostal water-trap drainage following operation was not found. In fact, Lund believed that airtight drainage was a disadvantage. Fowler employed a gauze pack which he changed frequently. In most instances irrigations of varying chemical composition were used soon after operation. On the average, pulmonary re-expansion was extremely slow, taking as long as nine months in some cases.

A complete description of decortication appeared again in 1915 when Lilienthal[16] described his major intercostal thoracotomy with lung mobilization.

Apparently this was the first attempt to treat acute empyema by decortication. At that time, Lilienthal developed his procedure because of dissatisfaction with the high mortality from rib resection (25 per cent) and with the relatively large number of secondary operations necessary (23 per cent).[30] In some acute empyemas of ten days' duration, major thoracotomy was performed both with and without prior intercostal waterseal drainage of the empyema (so-called minor intercostal thoracotomy). Adequate exposure was obtained without section or resection of ribs. Pus and fibrin were evacuated and partially sealed-off loculi of infection were uncovered. Lilienthal routinely removed a thick coating of organizing fibrin which was adherent to the visceral pleura. He rightly interpreted his findings as showing normal pleura and an expansile lung, unless, of course, pneumonia was still present. He emphasized freeing of the pulmonary base from the diaphragm but warned against separating the lung from the mediastinum, pericardium, or thoracic wall, as this might lead to a spread of infection or severe hemorrhage. Drainage was by open tube through the incision and wound infections were common. A certain number of revision operations were necessary and the mortality was high (19 per cent) by present-day standards. In a period of three years, however, no collapsing operations were done, whereas prior to that time approximately 20 per cent needed some type of thoracoplasty. Lilienthal[29] also used thoracotomy with rib resection and lung mobilization in cases of chronic empyema and again recognized correctly that the membrane which he removed was not thickened pleura but a tough, fibrotic sheet which was firmly adherent to a relatively normal visceral pleura. The membrane overlying the parietal pleura was not removed. Battle[20] likewise emphasized that the costal pleural component of the membrane should be allowed to remain, thus saving operating time and diminishing the loss of blood.

Violet[7] recognized that in certain cases decortication could not be performed because of chronic fibrosis of the lung. This was substantiated by the observations of Brouardel[31] and Charcot.[32] In rare cases a pleurogenic pneumonia was described[31] in which, as early as the thirteenth day, the lung was atelectatic and the interstitial tissue increased, thus preventing re-expansion. Violet believed intervention should be early, "as soon as the empyema has lost its spontaneous tendency to cure . . . when the two walls remain rigid, separated by too great a space." Most American surgeons have been of the opinion that many months should elapse before undertaking decortication and that other methods of treatment should be tried first. Lockwood[33] stated that there were more failures with decortication in cavities of from six to eighteen months' duration than in those of longer standing.

An early series of results was published by Violet in 1904. Combined statistics of his, and Kurpfweit's and Cestan's[7] 160 cases showed 41.9 per cent well, 12.5 per cent improved, 33.1 per cent unsuccessful, and 12.5 per cent dead. At that time the death rate was considerably less than for either the Estlander or Schede operations. Tuffier[34] reported 48 per cent cures and 15 per cent mortality in his series of decortications. In the treatment of 150 patients with chronic empyema, Hedblom[10] found that decortication had been used in thirty. There

was complete cure from decortication alone in 50 per cent and another 25 per cent were improved or cured by small secondary plastic operations. There was one operative death (3.3 per cent).

One final fact of importance should be considered. In the voluminous literature on empyema there has been little attempt to separate posttraumatic and hemothoracic empyemas from meta or postpneumonic empyemas, yet significant differences do exist and must be recognized if we are to approach properly the problem of posttraumatic empyema. Churchill[35] has suggested that this lack of differentiation during World War I might have been due to the great number of influenzal empyemas which largely overshadowed the post-traumatic cases in numbers and interest. Several surgeons have remarked on this difference in the past, but their observations have been all but lost and forgotten.

Delorme[36] stated that posttraumatic empyemas were very favorable for decortication. Turner[18] described empyema following hemothorax as much more serious than ordinary empyema with more drastic measures often demanded for its cure. "The pathology is essentially different, for here (infected hemothorax) we are dealing with a serous sac filled with masses of blood clots which have become infected and are slowly disintegrating." Both Battle and Spencer[21] recognized the essential pathology of pulmonary compression in posttraumatic empyema and favored relatively early decortication. Moynihan was cognizant of the importance of freeing the lung from constricting adhesions (organizing hemothorax) when thoracotomy was performed for the removal of missiles, and felt that on many occasions liberation of the lung was the more important of the two indications for operation. His patients in whom obvious empyema was present at the time of surgery, however, seemed very little benefited by operation.

In essence, the general status of decortication at the beginning of World War II was approximately as follows. In the oldest and most refractory cases,[27] decortication was of little use. The operation was reserved almost entirely for chronic empyema (excepting Lilienthal's[16] and Ware's[37] series). When the operation was attempted after months or years of disease, less than one-half of the patients were cured and mortality remained high, since hemo-organization or suppuration resulted in fibrous synechia between constricting membrane and pleura, and often led to pulmonary fibrosis. Decortication usually was not complete, in that the outer surface of the lung and the fissures only were liberated, without attention to visceroparietal, mediastinal, and pericardial separation. Additional factors militating against success, particularly in the earlier years, were lack of adequate anesthesia, blood transfusions, and chemotherapy. No essential distinction was made between postpneumonic and posttraumatic (hemothoracic) empyema. An excellent summary of the situation is that of Graham:[17] "Extensive decortication is usually accompanied by a large amount of hemorrhage. In many cases it is impossible to accomplish an extensive decortication because the fibrous tissue on the surface of the lung is only part of a more general fibrosis of the whole lung, and projections of scar tissue extend from the surface deep into the substance of the lung."

BASIS FOR PRESENT CONCEPT OF DECORTICATION

Based primarily on a wide experience with hemothorax and its complications of organization and infection, the indications for decortication have been broadened and operative technique has been modified. Approximately ten per cent of patients with battle-incurred traumatic hemothorax showed evidence of extensive clotting[38-40] and in nearly all of these there was some degree of organization. Clinical infection developed in a much larger proportion of clotted than of nonclotted hemothoraces.

In May, 1943, one of us (T. H. B.) performed a decortication in a case of uninfected organizing hemothorax five weeks after injury. Following this experience, detailed studies were made of the pathogenesis of hemo-organization. These have been described in detail elsewhere[41-43] and have been most fruitful in clarifying our therapeutic approach to the problem of organizing and infected hemothorax. In brief, the process of hemo-organization begins with the laying down of a thin film of fibrin and blood cells over both pleural surfaces. In the presence of this loosely adherent blood clot there follows early angioblastic and fibroblastic proliferation which extends into the clot from the pleurae. The hemothorax thus becomes a closed hematoma of the pleural space, the wall of the envelope being composed of an ever thickening layer of fibroblastic and later, fibrous tissue (Figs. 1 and 2). *The pleura itself does not become thickened* but remains a thin, translucent, grossly normal membrane. Further proof of the normalcy of the pleura has been gained by study of sections of peel stained for elasitc tissue. None has ever been found in the peel itself. However, in sections knowingly taken into the lung or tissues of the thoracic wall, elastic fibers always have been found just beneath the pleural mesothelium. Within three or four weeks, the outer or older aspect of the peel (that aspect next to the pleural surfaces) shows adult fibrous tissue whose fibers and nuclei have become arranged roughly parallel to the surface. The long axis of the capillaries remains at right angles to the surface and the capillaries are continuous through the pleura (Fig. 3). Within seven weeks, small arterioles with smooth muscle fibers in the walls can be demonstrated at or near the outer aspect of the peel. Along the inner or younger surface of the peel active fibroplasia continues, resulting in progressive thickening. When fully developed, the peel or rind forms a tough, inelastic membrane one or more centimeters in thickness, and that portion of the envelope which invests the visceral pleura effectively prevents pulmonary re-expansion. The segment of the envelope overlying the parietal pleura is always thicker, more adherent, and more vascular than is the visceral segment. In many cases, as weeks pass, the fibrosis increases and tufts of scar tissue extend through the pleura into the interstitial tissue of the lung. Such a degree of cellular intimacy develops between pleura and peel that a cleavage place may be difficult if not impossible to establish and the invaded lung becomes poorly expansile. Calcium may be deposited in the peel within three or four weeks. In some cases layers of fat cells have developed in the peel along the

older or pleural surface. This may be a regressive process heralding, in these individuals, eventual degeneration and absorption of the peel.

The success of early decortication depends on recognizing the factors just enumerated. The occurrence of infection in a hemothorax does not change the essential pathology of hemo-organization although a firmer, thicker membrane certainly develops more rapidly in many cases when infection supervenes. Thus, in early empyema, decortications have been performed eleven and twelve days after injury and a tough, mature peel removed.

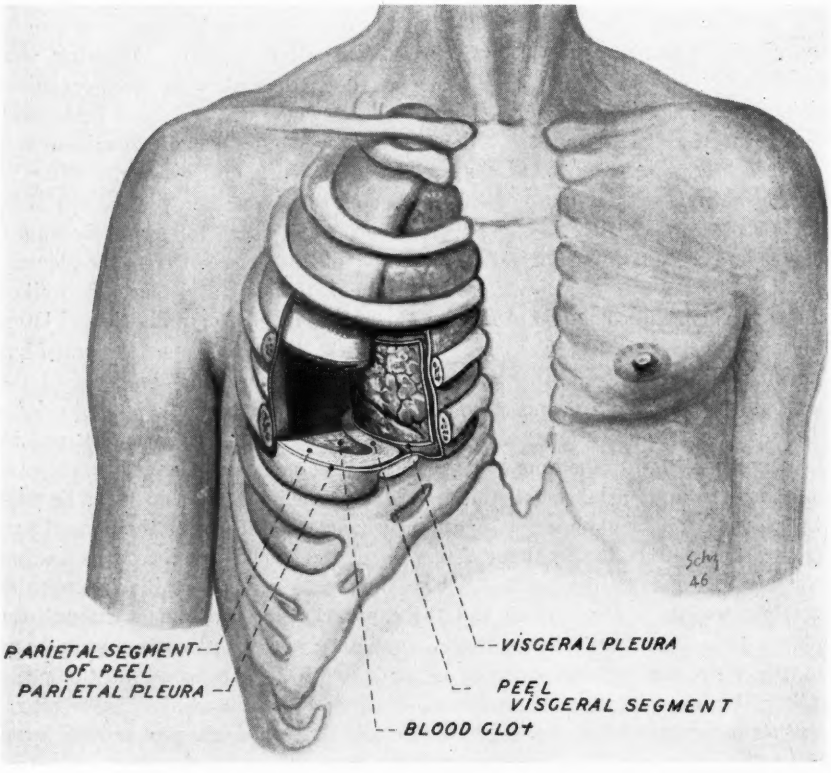


Fig. 1.—Semidiagramatic transparency showing relationship of an organizing hemothorax (closed intrapleural hematoma) to the collapsed right lung.

When decortication is decided on, proper timing is of the essence. If attempted within ten to fourteen days in uninfected cases, the peel is thin and friable. The operation is tedious because the poorly defined membrane must be stripped or wiped away piecemeal from the pleural surface. When performed too late the fibrous union between peel and pleura prevents a clean separation and the lung frequently is torn. From a technical standpoint, the peel is most easily removed in from three to five weeks in uninfected cases, and usually somewhat earlier (two to three weeks) when infection develops rapidly.

THE OPERATION

Decortication entails open thoracotomy, and the technique of operation has not differed appreciably whether or not infection was present in the hemothorax. Neither attempted clot evacuation by waterseal intercostal catheter nor clot removal alone at the time of thoracotomy has been an adequate procedure. Pulmonary re-expansion following such operations has been disappointing. Endotracheal anesthesia has been employed with gas, oxygen and ether, or cyclopropane. When caring for battle casualties, unhealed wounds on the homolateral thorax were (1) closed secondarily prior to thoracotomy; (2) excised and closed at the time of thoracotomy, using a different set of instruments; and (3) isolated from the fresh incision.

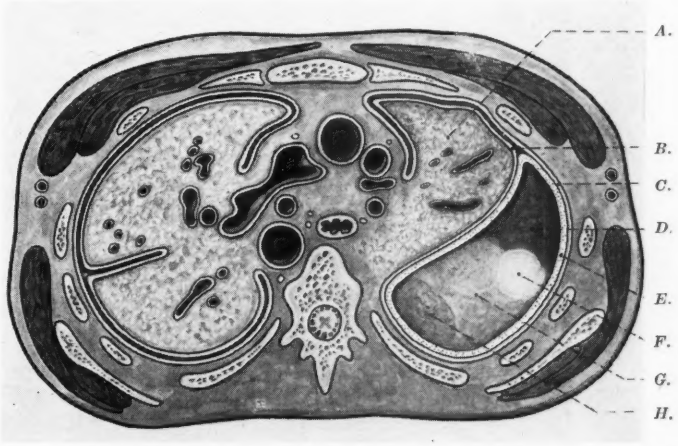


Fig. 2.—Cross section of chest: Right-sided, infected, organizing hemothorax showing loculation. *A*, Collapsed right lung; *B*, visceral pleura; *C*, parietal pleura; *D*, blood clot; *E*, peel or fibroblastic membrane adherent to pleurae and forming envelope of the closed hematoma; *F*, serum pocket; *G*, fibrinous partition; *H*, purulent portion.

In general, posterolateral incisions have been used. There is no serious objection to the removal of a rib posteriorly but if the approach is anterior, costal resection should not be performed. Excellent exposure can be gained by intercostal incision without section or resection of ribs, and this method is preferred by us. The exposure is facilitated by using two rib spreaders. Entrance usually is made through the sixth intercostal space, but the fifth or seventh may be used depending on whether better intrathoracic exposure is desired at the apex or at the base. Upon entering the pleural cavity the lung must be freed widely from the region of the incision, otherwise extensive tearing will take place when the ribs are separated. Since the lung often is compressed into the posterior gutter, it follows that much of this separation will be between visceral and parietal pleura, actually behind and mesial to the membranous envelope. Once freeing has been accomplished, rib spreaders are introduced and the blades are widened gradually, to allow for muscular relaxation.

Liquid exudate, clot fragments, and masses of fibrin are evacuated (Fig. 4). All loculi are broken down. If no bronchial fistulas are present, the cavity is thoroughly cleansed with saline solution. There remains a brownish-red surface with the appearance of shagreen leather. This is the inner or younger surface of the peel. The contours are smooth, anatomic landmarks are obliterated, and the underlying lung is relatively immobile.

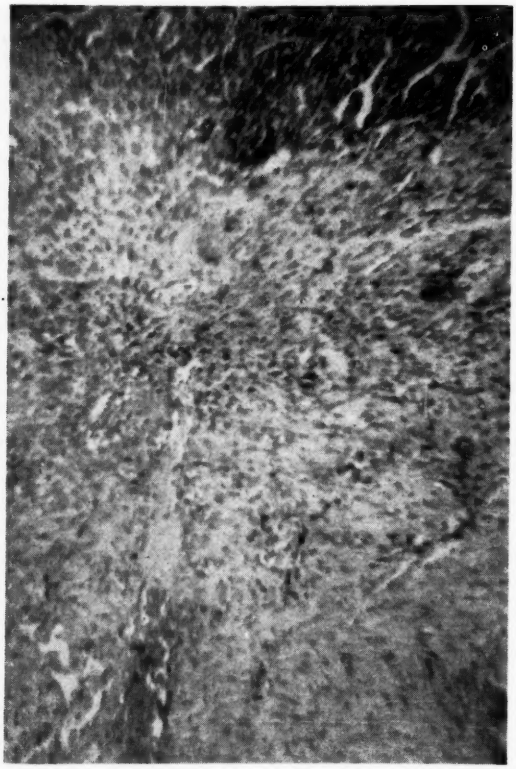


Fig. 3.—Cross section of peel in organizing hemothorax of four weeks' duration (×250). At the top is the younger, more cellular fibroblastic tissue which forms the inner surface of the peel. At the bottom is adult fibrous tissue near the older or pleural surface of the peel. The long axis of the capillary is at right angles to the surfaces.

Sharp incision is made through the fibroblastic membrane to the visceral pleura (Fig. 5). This maneuver is facilitated by bracing the lung with moderate positive pressure. If the peel is several weeks old, it is usually laminated. Care should be taken that the pleura itself is exposed and that no laminations are allowed to remain, otherwise re-expansion will be greatly inhibited. As soon as visceral pleura is reached, the segment of underlying lung will herniate through the incised peel. The edge of the membrane is grasped by forceps and actual decortication is begun (Figs. 6 and 7). During separation the main pressure

is directed toward the peel using either small gauge dissectors or the fingers. The palmar surfaces face toward the peel and are employed in a sweeping motion, the backs of the fingers being toward the lungs. There is widespread oozing from the visceral pleural surface but this can be readily controlled by warm packs and gentle pulmonary expansion under positive pressure.

Care is taken not to tear the lung, particularly around freshly healed wounds, in the region of fistulas, or at the fissural margins. Decortication is carried to the edge of the collapsed lung where the peel reflects onto the parietal pleura (Fig. 8). The fissures and apex are then freed and the lung separated from the diaphragm, mediastinum, and pericardium, down to the hilum and pulmonary ligament. This is a most important part of the procedure. Complete separation must be carried out if rapid, circumferential re-expansion is to be obtained. The peel is excised along its line of reflection at the edges of the lung.

Fig. 4.—Photograph showing interior of thorax in a case of early, hemothoracic empyema. Note consistency of fibrinopurulent exudate held in forceps.

All freed strands of membrane are removed and the margins of the excised peel smoothed flat. Any compromise with this end will result in pocketing of secretions and reinfection. Tough patches of secondary membrane which cause the lung to crease or fold on re-expansion should be removed or incised. No attempt has been made to remove membrane from the parietal pleura. This has no effect on pulmonary re-expansion and the oozing is extensive and difficult to control. We believe that routine parietal decortication increases the risk of

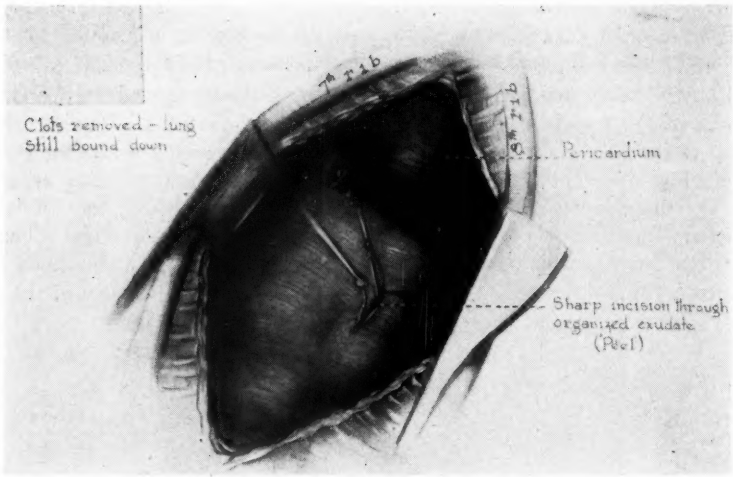


Fig. 5.—Drawing at operation after removal of exudate, showing method of establishing cleavage plane by sharp incision through peel.

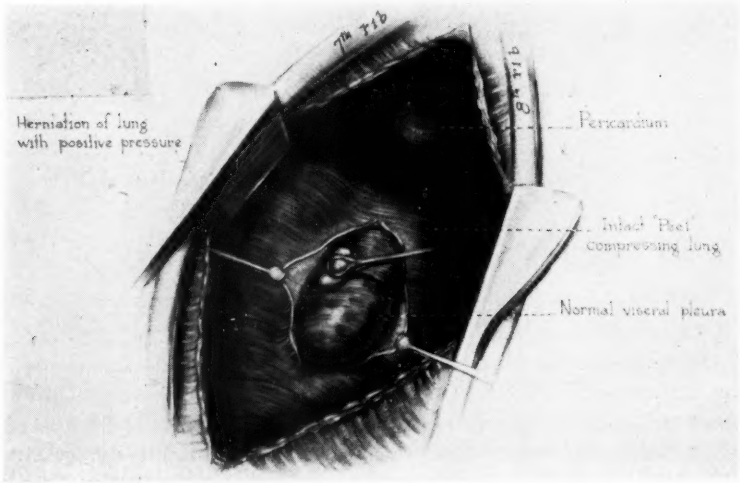


Fig. 6.—With application of positive pressure the lung bulges through the incision in the peel. Visceral pleura is normal. Actual decortication is begun using gauze or finger dissection.

operation without adding appreciably to its benefits. The costal segment of the peel is, however, scraped and scrubbed with gauze to remove fibrin and make the surface smooth. The diaphragm need not necessarily be decorticated although this can be usually performed without difficulty. The costophrenic and cardiophrenic sulci should be re-established to increase diaphragmatic motion and aid in pulmonary re-expansion.

Following initial release of the lung, intermittent expansion under increasing positive pressure should be practiced. We believe this is preferable to attempting sudden, complete re-expansion at the end of operation. The visceral pleura should be kept moist, and atelectatic areas gently stroked while the lung is being expanded. Usually the lung will almost completely fill the pleural cavity before the chest is closed (Figs. 9 and 10).

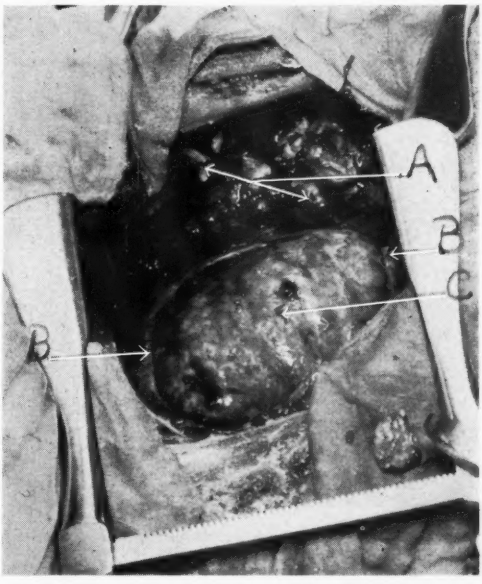


Fig. 7.—Photograph after removal of oval segment of peel. The lung is under positive pressure. *A*, Segment of peel overlying parietal pleura; *B*, cut edge of peel which has been compressing lung; *C*, herniating lung.

After the lung has been freed, attention is given to necessary pulmonary surgery. Tears in the visceral pleura resulting in air leaks are repaired with interrupted fine silk. Single superficial fistulas may be closed after freshening the edges. Intrapulmonary foreign bodies usually are impossible to locate beneath the peel in a compressed lung. Following decortication, however, they can be readily palpated and removed. Post-traumatic intrapulmonary infection may cause considerable difficulty. Infected hematomas and abscesses usually have been opened, the necrotic lining membrane removed by dissection and the dead space eliminated by layered closure with fine silk. It must be emphasized

that a post-traumatic abscess bears little relation to an ordinary pulmonary abscess. The former may occupy any portion of the pulmonary parenchyma. It is due to local tissue damage and necrosis, with the secondary infection almost always introduced from without, rather than through the bronchi. If an abscess or damaged lung with multiple fistulas is peripheral either at the fissures or at the base of the lower lobe, a wedge resection may be done (Figs. 11 and 12). Total lobectomy may also be performed but this has not been necessary in our experience. In so far as possible, long sinus tracks in the lung must be laid open, the lining membrane curetted, and the lung closed in layers. Mere closure of the superficial openings of a sinus track will not suffice.

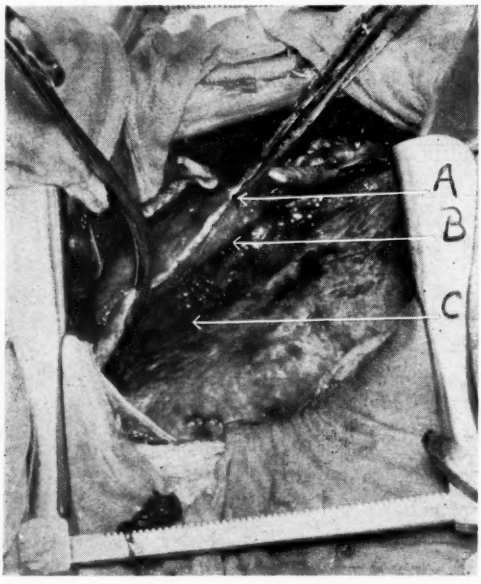


Fig. 8.—The lung has been freed anteriorly as far as the thoracic wall by removing the peel to the point of its reflection from the visceral onto the parietal pleura. *A*, Cut edge of peel; *B*, line of reflection of peel onto parietal pleura; *C*, anterior margin of collapsed lung.

The inner thoracic wall is inspected and palpated for the presence of rib splinters or metallic fragments. Those which protrude into the pleural cavity are removed and a smooth surface achieved.

Provision for the maintenance of pulmonary expansion is provided by the insertion of two and sometimes three intercostal waterseal drains. One, a fenestrated soft rubber tube with an internal diameter of 6 mm., is introduced through the eighth intercostal space in the posterior axillary line. The inner end is tacked to the parietal pleura by a suture about 6 cm. within the cavity. If a previous rib resection for pleural drainage has been performed and the sinus is in the proper position for dependent drainage, this track may be used for the posterior tube. A second tube, preferably a Pezzer catheter, is brought out in the first or

second intercostal space in the midclavicular line. If a third tube is employed, it is of the same type as the second and is brought out in the midclavicular line at the base.

Intercostal nerve injection of two or three nerves above and below the incision is done with one per cent procaine. The pleural cavity is lavaged thoroughly with at least 1,000 c.c. of normal saline solution, and final inspection is made to be certain that the cavity is clean and bleeding points are controlled.

Fig. 9.—After circumferential freeing, the lung has been re-expanded by positive pressure and it almost completely fills the thoracic cavity.

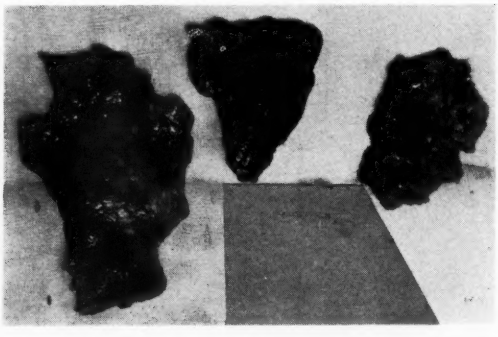
The lung is brought to complete expansion, the drainage tubes clamped, and a layered closure is performed, using interrupted fine silk. In the first layer the sutures are placed, the ribs approximated with Kon-jawed forceps or retractors, and all sutures then tied. Pericostal sutures are not used. Penicillin solution containing 1,000 units per cubic centimeter is injected into the anterior tubes and these are immediately connected to water-trap bottles. The posterior tube is clamped off for six hours to allow for time contact with penicillin. Most of the patients are bronchoscoped before leaving the operating table.

Blood is always given during operation, usually from 1,000 to 2,000 c.c. It is important that the patient enter his postoperative phase with a normal hematocrit.

Postoperative Management.—This differs little from any major thoracic case. For successful maintenance of pulmonary expansion deep breathing, forced expiration, and voluntary cough are mandatory. Transfusions may be

given in the first two or three postoperative days. Systemic penicillin is continued until the tubes are out and the patient has remained afebrile for seventy-two hours.

Tube management requires close supervision. Continuous patency is paramount until the lung has expanded. We have not found it necessary to use more negative suction than that developed in the ordinary water-trap bottle (i.e., from 8 to 10 cm. of water). Irrigations are not performed, nor are instillations made. The tubes should be "milked" at least twice daily. If the tubes have been placed correctly and no undue oozing has occurred, little trouble is encountered in maintaining drainage. The anterior tube may be removed as soon as the upper lobe has expanded and begun to adhere, usually in from forty-eight to seventy-two hours. The posterior tube is not removed as long as drainage persists, which may be from seven to ten days in some cases. If a fistula develops, the anterior tube must be kept in place as long as the air leak continues. In one case a fistula was present for thirteen days and the tube was left in place without intrapleural reinfection developing.



A. *B.* *C.*

Fig. 10.—Specimens of peel or fibroblastic membrane showing characteristic appearance. *A*, The outer or "older" surface (that surface adherent to the pleura). It is glistening in appearance and yellowish-brown in color. The dark punctate areas represent small petechial hemorrhages from the torn ends of the capillaries which traverse the peel. *B*, The inner or "younger" surface (that aspect in contact with the semiliquid elements of the hematoma). It is dark reddish-brown pebbled, and has the appearance of shagreen leather. *C*, Mass of free fibrinopurulent exudate (see Fig. 1).

If a basal empyema becomes manifest, as shown by a change to purulent drainage, dependent rib-resection drainage should be done at once. A large airtight tube is inserted and attached to a waterseal bottle to prevent possible secondary collapse of the lung.

Chemotherapy.—Since the advent of penicillin, all patients have been placed on intensive therapy for several days prior to operation. This consists of 25,000 units of penicillin given intramuscularly every three hours. In some cases, from 25,000 to 50,000 units have been injected daily into the pleural cavity, although the effects of this have been equivocal. At the time of operation the average amount injected into the pleural cavity has been 50,000 units. The preoperative dosage of penicillin has been continued for approximately two weeks following operation.

Before penicillin was available, from 5 to 10 Gm. of crystalline sulfanilamide were scattered in the pleural cavity and wound following decortication. In cases of severe or mixed infection we have not hesitated to insert both penicillin and sulfanilamide in the pleural cavity at the end of operation.

INDICATIONS FOR DECORTICATION

Uninfected Organizing Hemothorax.—These patients are observed and treated conservatively for from four to six weeks. It is technically difficult to remove a peel within two weeks, and experience has shown that many cases believed at two weeks to be eventual candidates for decortication, have shown satisfactory clearing and have become asymptomatic by the fifth or sixth week. Repeated efforts are made at aspiration and the removal of as little as 50 to 100 c.c. of currant jellylike material from time to time is known to be advantageous.

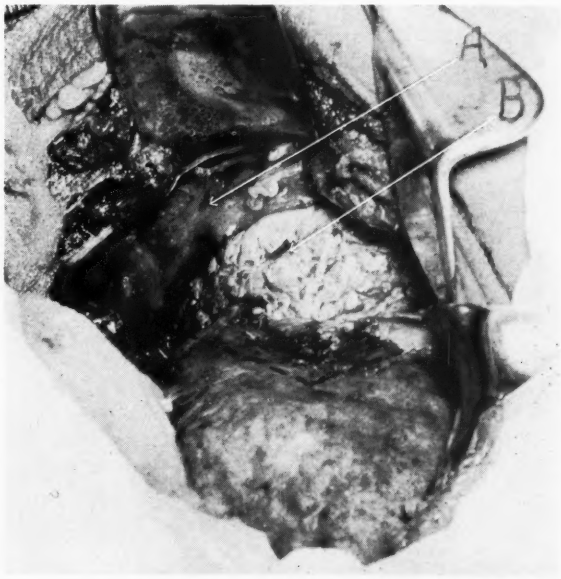


Fig. 11.—View toward the diaphragm. *A*, Decortication has been completed. The roughened, light-colored segment (*B*) is a peripheral area of necrotic infected lower lobe, covered with adherent fibrin and containing multiple fistulae, the result of a perforating shell fragment wound. The broken lines represent the extent of the wedge resection. Following resection and hemostasis, the raw surfaces of the wedge were approximated with sutures and the edges entirely pleuralized by a two-layered closure with fine silk.

It is probable that the breathing exercises as described by Harken[39] are important aids in re-expansion. If, at the end of five or six weeks, the situation has become stationary, decortication is indicated when a patient presents part or all of the following picture: roentgenographic evidence of a generalized hazy chest; lateral pulmonary compression of fifty per cent or more with a collapsed apex; poor thoracic expansion with retraction and narrowing of intercostal spaces; diffuse thoracic pain or discomfort; and dyspnea on exertion. Similar

indications have been employed by Coleman.[44] Many patients with a retained foreign body of a centimeter or more in diameter showed by the third or fourth week an upper lobe that was well expanded but a lower lobe still partially compressed by an organizing hemothorax. In such individuals, the combination of a retained foreign body and moderate degrees of organizing hemothorax was considered sufficient indication for decortication and removal of the missile.

Infected Organizing Hemothorax.—In all cases where the lung was compressed more than twenty-five per cent and particularly if the apex was collapsed, decortication was undertaken as soon after infection was discovered as the patient's condition would permit. Occasionally this occurred by the tenth to the twelfth day. Positive smears or cultures frequently could not be obtained and presumptive evidence of infection was based on signs of increasing toxicity, mounting fever, or rapid increase in the size of the hemothorax.

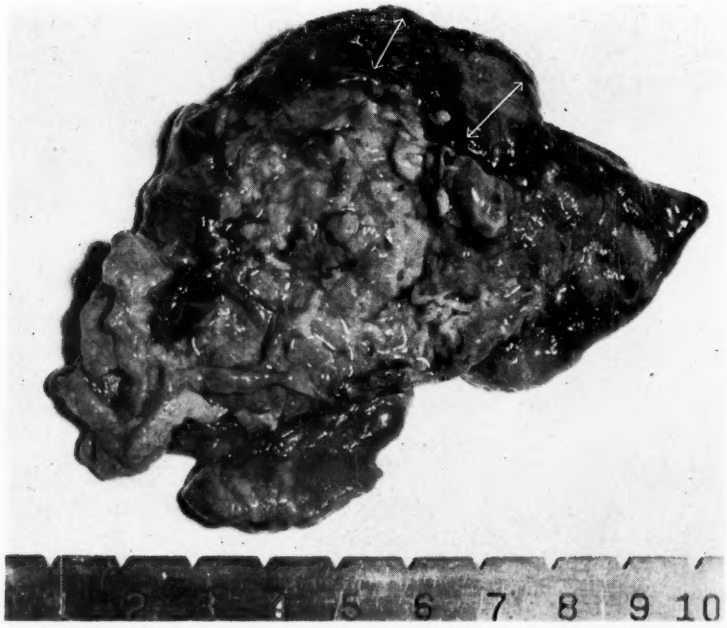


Fig. 12.—The resected segment of traumatized, infected lung. The diaphragmatic surface is toward the ruler. Arrows delimit the surface made by incision into normal pulmonary tissue (cf. the broken lines in Fig. 11).

Post-traumatic Empyema (Hemothoracic Empyema).—The difference between infected hemothorax and frank empyema is not great. In the latter instance the infection has been present for a longer period of time or may be more virulent. The patients in general are sicker, and the aspirated material is grossly purulent. In our early experience, patients with empyema were subjected to rib-resection drainage as soon as the exudate became purulent. When the empyema was total, or when it was less than total and sizeable intrathoracic missiles were present, decortication was carried out two to four weeks after

rib resection. By March, 1944, penicillin had become available and our technique was stabilized. At that time we began subjecting suitable cases to primary decortication without preliminary drainage.[41] The type of organism recovered was not a factor in the decision and clostridial empyemas were not treated differently from other types of infection. If the patient was profoundly toxic, preliminary rib resection drainage was performed followed by decortication as soon as the patient's condition warranted. All patients with empyema whose pulmonary compression was more than twenty-five per cent, particularly if the apex was collapsed, or who had large intrapleural or intrapulmonary foreign bodies, have been candidates for decortication.

DISCUSSION

We believe that the rationale of early decortication in selected cases of sterile organizing hemothorax, infected hemothorax, and post-traumatic or hemothoracic empyema has been adequately demonstrated. The philosophy is now untenable which holds the patient with massive hemothorax to be convalescing satisfactorily as long as infection is not evident. The early restitution of pulmonary function has become a primary concern. The crippling effects of chronic fibrothorax are now preventable.

To those who advocate a more conservative approach in the therapy of post-traumatic empyema we emphasize the not insignificant mortality among adequately drained empyemas who apparently are doing well. Even the best managed case is unpredictable and the road from drainage to complete cure is beset with significant dangers. Chronicity may develop at any stage, and, at best, the time elapsing before a cure can be expected is a matter of many weeks, if not months.

Significant decortications have been performed on approximately 125 patients. There was only one total failure in decortication, and this patient was operated on early in our experience. There have been no operative deaths among our patients and no wound sepsis. Two patients developed superficial wound infections. In the group with recognized intrapleural infection, slightly over 75 per cent had primary healing and complete pulmonary restoration without the development of recurrent empyema. The great majority of residual empyemas were small and basal in location. They responded excellently to adequate rib-resection drainage. All patients not obtaining primary cure could be said to have benefited from decortication. Of considerable significance in assessing the value of decortication is a study of results in patients with and without pulmonary infection or fistulas. Where the lung was normal at the time of decortication, over 90 per cent obtained primary cure, while in the group with associated pulmonary pathology, some 40 per cent had recurrent empyema. The results cited above have been approximated by our colleagues in other thoracic centers both at home and abroad.[39, 45-47] It is estimated that in the neighborhood of 1,500 early decortications have been performed for indications similar to ours, with an operative mortality of probably less than 2 per cent.

Lest those unfamiliar with the operation be deluded by the excellence of these figures into thinking that total pulmonary decortication is not major

surgery, let me emphasize that: (1) the operation is one of considerable magnitude; (2) normal hematocrit and serum protein levels are essential preoperatively; (3 chemotherapeutic bacteriostasis should be manifested prior to operation; (4) large amounts of blood must be available during surgery; and (5) the services of a competent thoracic anesthesiologist are mandatory. Compromise with these basic principles means the return of morbidity and mortality figures to prohibitive levels.

Our experience with early decortication in postpneumonic empyema has been limited. In most cases, however, it is apparent that a fibrinofibrous membrane develops, similar to that routinely found in organizing hemothorax. The microscopic appearance of such a membrane was described many years ago by Graham.[17] It is further obvious from our own experience as well as that of Lilienthal,[16] Sanger,[48] and others, that in the early phase of postpneumonic empyema at least, the pleura is essentially normal. These facts point the way to employment of early decortication in selected cases of subacute or impending, chronic, postpneumonic empyema. In general, indications should be those of a total or subtotal empyema, with collapsed apex. Loculation of the exudate should be a further reason for considering decortication.

Finally, there remains the question of treatment in tuberculous empyema when there is no parenchymal infection. Scattered in the literature are references to late decortication in such cases.[3, 10] We believe that early decortication is technically possible in patients with acute or subacute total tuberculous empyema, but whether or not operation should be used in such cases cannot be finally decided at the present time.

SUMMARY

1. The origins of decortication have been outlined and evolution of the operation has been traced.

2. The surgeons chiefly responsible for contributions to operative technique have been cited.

3. The pathogenesis of hemo-organization has been described.

4. The newer concept of total pulmonary decortication as an early procedure has been presented, based primarily on a broad experience with traumatic hemothorax and its complications of organization and infection.

5. The technique of operation has been given.

6. The indications for operation have been discussed.

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DISCUSSION ON "THE PATHOLOGY OF CHRONIC, TRAUMATIC HEMOTHORAX" BY DR. HIRAM T. LANGSTON AND DR. WILLIAM M. TUTTLE,* "THE TREATMENT OF ORGANIZING HEMOTHORAX BY PULMONARY DECORTICATION" BY DR. W. M. TUTTLE, DR. H. T. LANGSTON, AND DR. R. T. CROWLEY,† AND "TOTAL PULMONARY DECORTICATION: ITS EVOLUTION AND PRESENT CONCEPTS OF INDICATIONS AND OPERATIVE TECHNIQUE" BY DR. PAUL D. SAMSON AND DR. THOMAS H. BURFORD‡

DR. GEORGE N. J. SOMMER, JR., Trenton, N. J.—I wish to show two cases that illustrate problems arising in the treatment of clotted hemothorax.

(Slide.) The first patient was admitted with total collapse of the lung. Fluid had been aspirated from the pleural cavity and efforts had been made prior to admission to expand the left lung. Further efforts were made, but only partial expansion was obtained due to the scar tissue on the visceral pleura and a large bronchopleural fistula.

At operation the lung was found to be totally collapsed. The restricting scar tissue was readily removed and a very small partial resection of the lower lobe was performed at the site of the bronchopleural fistula. The lung had been adherent to the diaphragm in the region of the fistula.

I have not heard of any case similar to this one, but do not doubt that they have occurred. One additional case of the same type was treated at our thoracic center.

(Slide.) The roentgenogram shows the entirely expanded lung three weeks following operation. The patient was then ready for transfer to the United States.

At the onset of our work with clotted hemothorax, we used only one intercostal drainage tube following operation. As Dr. Samson has mentioned, two or three tubes are necessary.

(Slide.) The next patient was a prisoner of war who was admitted with a large, clotted hemothorax.

(Slide.) The lateral film shows the size of the clotted hemothorax. Frequently, the large amount of blood present is not apparent without a lateral film, which, in this case, also demonstrates the large intrapleural foreign body present.

(Slide.) After decortication, the patient's pleural cavity was drained with one intercostal tube. Re-expansion of the lung was not obtained. This film, taken four weeks following operation, shows the lung covered with the same type of fibrous scar tissue as prior to operation. Another drainage tube was introduced, which can just be seen in the slide. An endeavor was made to expand the lung with high negative suction. The effort failed due to the bronchial fistula and the scar tissue over the lung. A secondary decortication was carried out. A well-formed scar was found over the visceral pleura and was readily removed. The thoracic wall was closed and the pleural cavity drained with two intercostal tubes. The lung re-expanded completely.

(Slide.) One additional point should be made. This film, taken about two months after operation, shows a marked scoliosis. This is undesirable in any patient after a thoracic injury or thoracotomy. The scoliosis should have been prevented by adequate breathing exercises, which had been neglected by this patient.

DR. LEON J. LEAHY, Buffalo, N. Y.—It is with humility that I report this case, in view of the large series mentioned early in the program. It brings out the point that this principle is adaptable to the rehabilitation of civilians as well as military personnel.

This man was in a city distant from Buffalo and in the early part of February had an acute upper respiratory infection which apparently was quite severe. After two weeks of this, there was a sudden episode of pain in the chest, he was taken to the hospital, x-rayed, and a spontaneous pneumothorax was found. It was relieved by aspiration of the air. However, four hours later fluid was seen, and subsequent aspiration revealed blood.

*See page 99 for article by Langston and Tuttle.
†See page 117 for article by Tuttle, Langston and Crowley.
‡See page 127 for article by Samson and Burford

After six weeks, he was brought to Buffalo, in oxygen, with a temperature up to 105° F. We tried repeated aspiration without avail. We could empty the pockets of old blood and air, but there was no improvement in the re-expansion. Decortication was done as outlined in the slides. The material aspirated did not produce bacterial growth on any of the usual media. The hematoma removed at operation was also sterile, even in the center.

The lung was very much like an orange which could be peeled. We freed the entire lung and fissures and the mediastinal portion of the parietal pleura, although it did not re-expand under mild positive pressure. There were no air leaks.

(Slide.) This was immediately after the acute episode. It shows an adhesion band of the apex.

(Slide.) The second slide shows the fluid level with disappearance of adhesion band. This caused me to speculate as to the origin of the blood; whether it came from needle trauma or whether the adhesion band snapped and caused bleeding into the pleural cavity, I do not know.

(Slide.) We operated at the end of eight and a half weeks, and this is the film taken eight days postoperatively. At the time of surgery, the lung did not re-expand and we were rather discouraged.

This slide, taken thirty days later, still did not look promising; although there is a large percentage of expansion, the slide shows small pneumothorax at the apex, and a small amount of fluid at the base.

A film taken last Friday, which was six weeks postoperative, shows complete expansion and no fluid. The man is a chemist and is ready to return to work. If this procedure had not been emphasized in the theaters of war, he would have been a respiratory cripple for a long period, if not permanently.

DR. JOHN M. CHAMBERLAIN, Cooperstown, N. Y.—In a small series of cases in a Field Hospital which served a Japanese prison camp, we stressed not only re-expansion of the lung, but early restoration of pulmonary function as well. In our effort to regain normal function we removed all three elements forming the capsule of the pleural pocket; namely, the visceral, diaphragmatic, and parietal elements. In addition to this technical point, the patients were urged to exercise early or very soon after operation. All patients, with one exception, were ambulatory the first day following operation, and walked some 50 yards to the x-ray tent for their morning x-rays.

Our technique did not vary from Dr. Samson's in any way, except that in the removal of the parietal element we waited until the visceral element was completely removed, and then by returning to the original incision found the cleavage plane between the parietal element and the chest wall. The separation of the parietal element from the chest wall was quickly accomplished with a finger or other blunt instrument and continued on until the previous field of dissection was encountered along a line where the visceral element is reflected onto the parietal pleura.

It seemed to us that by removal of all three elements, pulmonary function was more quickly restored. I am sure that we were not the first to do this, nor the only ones, and perhaps such a procedure has some merit.

DR. ALFRED GOLDMAN, Los Angeles, Calif.—I would like to describe two patients seen at the University of California Hospital and Clinic, who illustrate some of the problems that will come up now that decortication has entered the field of therapy for chronic hemothorax in civilian life.

(Slide.) The first patient is a girl, 7 years of age, who was a private patient of Dr. Lyons of our staff. She was struck by a truck on Feb. 13, 1945, and this is an x-ray taken four days afterward. Aside from chest injuries, there were a fractured skull and fractured tibia. She was very sick at this time. One can see that the right lung now occupies the center of the chest and is pushed into that position by the clotted hemothorax in the right chest.

(Slide). She was treated with aspirations, but the clotted hemothorax persisted, and and one month after the accident, decortication was done. At this time she still had fever up to 103° F.

(Slide.) This shows the postoperative film, approximately thirty days after the operation. The lung has almost completely re-expanded. During the operation, contused lung was also removed.

I would like to abstract the pathologic report. The clinical diagnosis was traumatic hemothorax. Specimens consisted of one large 7½ by 4 cm. and numerous small pieces of tissue. One surface of the large piece was smooth, shiny, and gray. It was a translucent membrane which was elastic and stripped with ease, and beneath it could be seen reddish tissue, divided by pinkish tissue. The reddish surface was succulent. One border was covered with gray membrane as described. I think this is similar to Dr. Samson's case, in which contused lung was removed with the membrane.

The other pieces of tissue were similar to the last described tissue. They were cream to red in color, and showed no membrane. Microscopically, the membranes and lung showed essentially the patterns that we saw in Dr. Samson's sections.

(Slide.) This is the last x-ray, approximately two months after operation: the lung has re-expanded and returned to its normal position.

(Slide). The second patient was a man 30 years of age, an American Indian, who suffered an automobile accident with multiple fractures of the ribs two days before this x-ray was taken. Here the entire right chest is opaque from a clotted hemothorax.

This man, in addition to his multiple fractured ribs, had a picture of acute condition of the abdomen requiring surgery, with extreme tenderness and rigidity of the entire right upper quadrant, but no intra-abdominal injury was found.

(Slide.) This x-ray was taken the day before operation, five and a half weeks later. The aspirations which were performed failed to change the x-ray picture very much. The patient was still running a low-grade fever when decortication was done.

(Slide.) Through a transpleural, posterolateral approach the seventh rib was removed; in the pleural cavity, the site of the fractured sixth rib could be seen as a red, contused, oozing area. This brings up the point that many clotted hemothoraces in civilian life probably will be due to intercostal hemorrhage rather than hemorrhage from the lung.

The sixth, seventh, and a portion of the eighth rib were removed. Decortication was done in the same fashion as Dr. Samson indicated in his paper, the lung unfolding and expanding freely as the membrane was peeled off; nowhere was the lung contused.

(Slide.) This is approximately one week after operation, when the tubes had been removed and the lung had already expanded almost completely.

(Slide.) This is a slide three months after operation, showing completely expanded lung.

DR. DONALD PAULSON, Dallas, Tex.—I should like to take just a few moments to discuss the problem of decortication as we saw it in the thoracic centers within the zone of the interior. We saw these patients at a later stage in our series at Brook General Hospital. Most of the cases were of over three months' duration. In one instance, the lung had been bound down by this constrictive pleuritis for over a year's time. The problem later I believe is a little bit different from the problem of early decortication, as we found it.

We developed a technique which I am sure is not original, but which was necessitated by the very thickened fibroblastic membrane on both the parietal and visceral surfaces, as well as the diaphragmatic surface. Originally, we followed the technique described by Dr. Samson and Dr. Tuttle, and arrived at our technique in this way. We found that in certain cases it was very difficult, and practically impossible, to dissect the fibroblastic membrane from the visceral parietes as the initial step in the procedure. We separated the thickened, fibroblastic membrane from the parietal surface first; that is, we entered the area of the endothoracic fascia and dissected this thickened area back down to the line of deflection from the parietal to the visceral surface. After passing through this line of deflection, a zone of filmy adhesions is encountered and pneumonolysis may be done very easily.

After completely separating this fibroblastic membrane from the parietes and the diaphragm, it is then grasped with forceps, and with the lung expanded under positive pressure, the incision of the lung surface itself is done very easily.

I would like to show one slide to illustrate this technique.

(Slide.) It is very diagrammatic. It illustrates the original incision through the thickened fibroblastic membrane. The dissection proceeds posteriorly down to there. The line of deflection from the chest wall to the visceral surface is entered, and right there we find the filmy adhesions. With the finger within this zone forming adhesions, the peel is easily separated by means of scissors in the direction of the apex to the diaphragm, and in the same way it is separated anteriorly. After completely separating the fibroblastic membrane from the parietes and diaphragm, this membrane is grasped with forceps and the lung is expanded under positive pressure, and then by means of sharp dissection, it is dissected free from visceral pleura.

We have used this procedure in most of our cases. The distribution of cases was not entirely secondary to the type of hemothorax. We had several cases of organized pleural fusion. In one instance it was secondary to subphrenic abscess. The pleural fusion organized, and decortication was necessary to obtain expansion of the lung. Decortication of the pleura was done in one case and of diverticular pleuritis in five cases.

Dr. Tuttle mentioned that in five cases he believed the thoracoplasty procedure was necessary at a later date. I rather suspect in hospitals in the zone of the interior those cases were subjected to repeated decortication.

We had one case which was a very severe test for decortication. The patient was admitted with wide open chest from the drainage of infected hemothorax. The lung was plastered down against the mediastinum. It was necessary to do four separate decortications before complete expansion of the lung was obtained. Thoracoplasty procedure was avoided.

DR. CARL EGGERS, New York, N. Y.—The application of decortication of the lung to hemothorax as presented this morning is new, and the results obtained are so striking that the operation merits our attention. During World War I, as well as in civilian practice since then, there has been considerable difference of opinion concerning the best method of treatment. It was known that if left untreated, closed hemothorax would produce a disabling fibrothorax. In many instances the treatment consisted of rest and physical therapy, while other surgeons practiced repeated aspiration. Only in infected cases was drainage instituted and the condition treated as an empyema.

During World War II, the early grouping of chest injuries at thoracic centers enabled surgeons stationed there to make a careful study of the pathology and course of hemothorax, which led to the treatment by decortication as presented here. The authors deserve great credit for applying decortication with the brilliant results reported by them.

My own experience with hemothorax as such is limited, and I therefore feel hardly justified in discussing it. However, I am able to discuss the operation of decortication of the lung as applied to a different problem, namely, chronic empyema. This condition was one of the difficult residual lesions during and following World War II.

The two groups of cases differ considerably. In hemothorax we are dealing primarily with the result of trauma, while in chronic empyema we are dealing with the result of infection.

Uncomplicated hemothorax runs a rather benign course and, except in cases with extensive damage to the chest wall or in thoracoabdominal injuries, there is usually no infection present. At the time of injury during combat the patients are in fine physical condition with normally functioning organs. Except for loss of blood and accompanying shock, their resistance may be assumed to be good.

Chronic empyema patients on the other hand are chronic invalids who have survived lobar pneumonia or measles, influenza, or other camp diseases, with their complicating, frequently bilateral, bronchopneumonia, as well as prolonged sepsis and drainage of acute empyema. Their resistance is distinctly lowered and structural organic changes have taken place in the chest.

This difference in cases is further illustrated during operation. Dr. Samson reported that after making the incision a rib spreader is inserted and the thick layer of tissue overlying the lung is peeled off, allowing the lung to re-expand. Such a procedure presupposes a fairly intact and mobile chest wall, as well as an uninvolved or certainly not a seriously damaged lung. In chronic empyema on the other hand, pathologic changes have taken place in the chest wall, in the pleura, and frequently in the lung as well. It is not possible to insert a rib spreader after making the incision, because the ribs are frequently fused and they are firmly embedded in the thickened parietal pleura. Resection of short pieces of all of the ribs overlying the cavity is a prerequisite to mobilization of the chest wall. The parietal pleura, which is usually ½ inch or more in thickness, has to be removed next, exposing the floor of the cavity which represents compressed or collapsed lung covered by a thin inflammatory tissue layer. The most important step in the procedure is mobilization of this fixed lung. This is accomplished by resection of the thick tissue forming the angle of reflection from the parietal pleura onto the lung. The remaining layer on the lung is then peeled off if that is possible; otherwise, crisscross incisions are made. Sometimes complete re-expansion of the lung results; in other cases there is only partial expansion. The degree of expansion depends not only on the mobilization but on the condition of lung parenchyma itself. Fibrosis of the lung definitely prevents complete re-expansion. The final result therefore depends on several factors: mobilization of the chest wall, mobilization and the degree of re-expansion of the lung, and elimination of the infected lining of the empyema cavity.

We reported the results obtained in 146 cases of chronic empyema by the method just described, in the Annals of Surgery, Feb., 1923, pages 142 to 170; March, 1923, pages 327 to 353; and March, 1923, pages 375 to 378. There were five deaths in the series, a mortality of 3.4 per cent.

DR. E. F. BUTLER, Elmira, N. Y.—It was my privilege during World War I to participate with Dr. Eggers in the Walter Reed series of chronic empyema cases. Dr. Eggers has described the difficulties in caring for these old chronic cases. Decortication, as practiced in World War II, seems to have been a much simpler and less crippling operation.

The modern chemotherapeutic agents have altered the evolution of these empyema cases. The contents of the empyema cavity can apparently be sterilized, but these contents are not rapidly resorbed.

In these cases there comes a time when the surgeon must decide whether a crippling type of chronic empyema shall be allowed to develop, or shall be prevented by open operation and complete dissection of pyogenic membrane and empyema contents from the underlying pleural surfaces.

So it seems to me that the old and the new have met and that, as always, the old must bow to the new and acknowledge its superiority.

DR. FRASER B. GURD, Montreal, Que.—I rise to point out that the operation of decortication in chronic cases has been used by many senior members of the Association for a great many years. It was at the Boston meeting of this Association in 1921, which is a quarter of a century ago, that I presented a paper on the subject of decortication, and it was followed by a discussion.

Some of the older men in the room will remember the date at which, by resolution from the floor, the question of empyema was taboo as far as further presentation of the question before this Association was concerned. It was about 1928 or 1929. That is perhaps the reason why this question has been in abeyance in the intervening period.

Most of you will remember that in 1941, led by that senior member, Dr. Singleton, and his associate, Dr. Moore, the question of decortication in chronic empyema was again raised, and it was discussed at that time.

During the discussion the statement has been made that following the first stage of the war, that is, after 1918, there was an enormous number of cases of chronic empyema in consequence of the inadequate treament of hemothorax, wounds of the chest, and the complications which followed measles and the influenza epidemic.

As a matter of fact, that was not quite true, gentlemen. There were a limited number of cases, considering the hundreds of thousands of men involved and the thousands of wounded in the chest. The total number of cases in the Canadian Army and Navy, from both war wounds and as complications from the influenza epidemic, because in Canada we did not have the measles epidemic which you had on this side of the border, was comparatively small. In the American services also the total number of cases was not, I believe, great.

The cases from the Canadian services were, for the most part, accumulated at the Ste. Annes Military Hospital, and we admitted approximately seventy cases of chronic empyema. The duration of these cases varied in length of time from six and a half months to five years.

I should like to refer to one method of treatment of both acute empyema and, more particularly, hemothorax, one which we used during the last war and which has not been referred to today, namely that of chemical decortication.

We made it a practice at the clearing station, with the British Army, in the cases of hemothorax which could not be easily evacuated with the needle, to introduce a metal trocar between the ribs as an airtight procedure, and at hourly intervals to fill the chest with Dakin's solution. At the end of fifteen minutes, the Dakin's solution was run out as under water negative pressure.

This was kept up, as a rule, on the hour, forty-eight times, for forty-eight hours, and that form of decortication, in so far as the fibrinous mass covering the lung is concerned, proved to be effective in the majority of cases.

One other memorandum only, Mr. Chairman, and that is that since 1917 or 1918, in the postpneumonic pneumococcus type of empyema, we have made it a practice to remove a sufficient fragment of rib to allow the hand to be introduced into the chest, and in that way to carry out manually with a sponge what amounts to a very early decortication of the lung, although not in any way comparable to that of the two- or three-year-old case.

As the Chairman has pointed out, the problem is a very old one, or at any rate it is over a quarter of a century old. As far as this Association is concerned, it is a new one, and I and many others of my Canadian friends have been impressed by the excellence of the results obtained by Colonel Samson and Colonel Burford, Colonel Tuttle and his associates, and others.

DR. EDWARD D. CHURCHILL, Boston, Mass.—We are likely to miss a new principle that underlies this work on decortication. I rise in defense of the men who did this job, which I think is a real contribution to thoracic surgery.

Let us go back to the record. In 1940 this association appointed a committee to write a manual that would teach the young surgeons of the country how to treat chest wounds in World War II. Dr. Graham, Dr. Eloesser, Dr. Bigger, and myself constituted that committee. I can speak freely because I shared the responsibility.

In that manual we did not mention decortication. It is quite true that we did not go into the treatment of the late stages of chronic empyema. That was described as a matter for the specialist at the base. Whether, if we had discussed chronic empyema, we would have brought in decortication, is an open question, but I doubt it. This clearly records the negative evaluation of the procedure of decortication in the minds of the group, appointed by the Association at the beginning of the war. I believe it was representative of thoracic surgeons in general.

The manual did advise that in certain cases of infected hemothorax the chest might be opened, the hematoma evacuated, and closure made without drainage. We missed the point of taking off the peel and establishing immediate re-expansion of the lung.

The principle that underlies the procedure as developed in World War II can be formulated in a rather startling way. The principle which the Empyema Commission fought for so ably in World War I was to wait until a generalized empyema became localized, and then establish drainage. Many of us have fought and bled for years to get that idea across.

The procedure that Dr. Tuttle has described takes a localizing empyema and converts it into a generalized pleural contamination in order to gain re-expansion of the lung. Stated that way, an important principle is involved.

How far this principle is going to be applicable to the empyemas of civilian life remains to be seen. There is some reason to believe that treatment by chemotherapy during the acute pneumonic phase may control the invasive infection that ends in the pathologic condition quoted from Dr. Graham by Dr. Samson today. It is too early to speculate, but I do wish to point out that with the aid of chemotherapy and improved techniques we are no longer frightened of generalized pleural contamination. Dr. Tuttle and many others have boldly opened chests and freed the entire lung in the presence of a localized septic empyema. The purpose has been to restore the functional integrity of the lung. The results have proved the soundness of the concept.

DR. WILLIAM M. TUTTLE, Detroit, Mich.—I cannot say now how useful decortication of the lung will be in the treatment of civilian empyemas. It has become apparently obvious that we are seeing more and more patients with postpneumonic effusions, who have received intrapleural penicillin coupled with large doses of parenteral penicillin. These effusions are often inaspirable. When these pleural spaces are opened at thoracostomy, the pleural contents are found to be an organized mass of fibrin. When this is removed the lung does not expand nor show any inclinaiton to expansion. I have treated such individuals by simple open drainage and by decortication and there can be no question but what the latter gives much more satisfactory results. The period of convalescence following decortication is greatly reduced, for following such a procedure it is possible to remove the tubes within a few days and have a healed wound within a week to two weeks. When such a lesion is treated by drainage the period of morbidity is great and long and the possibility of a chronic empyema is considerable.

It may be argued by some that the illness does not justify the operative procedure. This I feel is not true. It is granted that a pulmonary decortication is a much more formidable operative procedure than a rib resection with drainage. However, the day has come when we can advise such procedures because they are safe, as has been shown by Major Langston and myself today. It is the function of surgery as we know it today to eradicate infected areas by more extensive surgery rather than complacently to be pleased by draining them.

The day has come when empyemas should not be allowed to become chronic when it is possible to prevent such a catastrophe. Whereas in days past we thought the infective process should be well localized before it was drained, today we must realize that it is possible to bring about needling in this type of pleural infection more rapidly by entering uninfected pleural areas in order that proper pulmonary expansion might take place. Pulmonary expansion has always been the method by which empyemas heal. Such a paradox in therapy will reduce the incidence of chronic empyemas as well as the prolonged period of healing that many empyemas require. It seems to me that it is quite as essential to effect rapid healing as it is to prevent chronic infections.

DR. EVARTS A. GRAHAM, St. Louis, Mo.—I feel that one point should be made and emphasized more strongly than it has been by the speakers, and that point is this: that when one makes comparisons with what we experienced in World War I with what has been experienced in World War II, the comparison really just doesn't exist. The similarity just does not exist between the two conditions.

Because I was one of the group that prepared this manual to which Dr. Churchill referred, I feel it is necessary to say a word of defense for that group, including myself, and including Dr. Churchill.

The difference is this. You men who have been working in World War II have not been seeing empyema. Empyema is an abscess of the pleural cavity. It is a word that was used by Hippocrates to mean abscess. You men have not been seeing abscesses of the pleural cavity. You have been seeing infections attenuated by drugs which were not known in 1941 when this manual was prepared, and much less known to Hippocrates. You were dealing with a condition which is totally different, something new in the world, something the like of which we have never seen before, pleural infection attenuated by penicillin.

Now there is no reason whatever why new principles of treatment should not be devised for the handling of this new condition, and I congratulate you young men for apparently

having found them, but let us not confuse this issue with what is really empyema, because what you have been talking about this morning at least is not empyema at all. If you had talked to Hippocrates about this as empyema, he would have said, "I don't understand what you are talking about."

DR. W. M. TUTTLE, Detroit, Mich.—I certainly do not like to disagree and take issue with Dr. Graham on the subject of the exact nature of the pleural accumulations which are under discussion, but there can be no doubt but that these were true empyemas. As far as I am able to determine, it makes little difference whether the infecting organism invades an already present accumulation of blood within the pleural cavity or the virgin pleura itself, except that in the former instance the field is more fertile. The very presence of such a pleasant habitat should, and I believe does, give rise to a more virulent type of empyema.

The material seen in these pleural spaces was purulent. It had often an extremely foul odor. It was laudable pus. Furthermore these soldiers were very ill with high elevations of temperature and pulse. If these were not instances of the clinical syndrome which we through the years have called empyema then I do not know what they were.

These were not patients with an attenuated form of empyema produced by the use of chemotherapeutic agents. Early in the war we had no penicillin. The sulfonamides were not used extensively. The first empyema decorticated by us was done successfully without the use of any chemotherapeutic agent. It must be remembered that the first decortication in a patient with empyema was done in January, 1944. There was not as far as I know any penicillin in the theater for such use until February, 1944. By the time penicillin was available for such patients we had already done a number of decortications of the lung in individuals who had infected hemothoraces. The sulfonamides were not used, as we felt that they did no good and were in some instances harmful. As time went on, in order to further prove the point at issue, we decorticated the lungs of a number of patients with infected hemothoraces without the use of any chemotherapeutic agent. The results were good. Such results can be accomplished only by careful surgery in which the lung is decorticated with infinite care so that the encasing and infolding is completely done away with. In patients so treated the lung will completely expand and the final outcome will be good.

DR. PAUL C. SAMSON, Oakland, Calif.—I am inclined to agree with Dr. Tuttle. I am sure I don't know what made these patients so thoroughly ill if it wasn't an infection.

Those of you who have had experience know exactly what I am talking about—the temperatures of 104 and 105° F.; pulses of 120 and 130. Perhaps it isn't empyema. Perhaps we should coin a new word. They were very sick from something.

I enjoyed Dr. Churchill's defense of the young surgeons, and also appreciated Dr. Butler's remarks, in attempting to use what we might call our broadened principles of decortication to compare the work of surgeons during and after the last war with what we have done during this war.

Time did not permit mentioning several other items which I believe are essential when we are speaking of our successes, first, that we had blood available in large quantities, and that was vital. Secondly, and I think practically as important as the surgery itself, was the fact that we had a group of anesthesiologists who were competent in the use of intertracheal tubes. Those two factors perhaps should be given fully as much credit as any advance in the surgery itself.

There has been some discussion among us who did decortications as to the advisability of removing the parietal pleura. Major Chamberlain brought that up. Dr. Burford's and my personal belief was that the segment of the peel over the parietal pleura, which is always thicker than that over the visceral pleura, did not have to be removed as a routine measure, in that the bleeding was more profuse, more difficult to control, and we could not see that pulmonary re-expansion was particularly benefited by removal of the parietal segment.

That may be open to some discussion, but in any event, our results were obtained without the routine removal of the parietal segment of the peel.

HEMOTHORAX AND EMPYEMA IN A THORACIC CENTER

GEORGE N. J. SOMMER, JR., M.D., TRENTON, N. J., AND WALDO O. MILLS, M.D., BOSTON, MASS.

IN THIS discussion, the problems associated with hemothorax and thoracic empyema following war wounds will be reviewed. There were 511 patients admitted to a thoracic center in England* during the compaigns of 1944-1945 in France and Germany. The patients were transferred from other hospitals and arrived at the center from three to eighty-three days following injury, with an average elapsed time since wounding of 32.1 days. Some data regarding thoracic wounds in a group of patients treated at a neighboring hospital are included.

There were 229 patients with fluid in the pleural space or with drained empyemas at the time of admission. The discussion is limited to these patients, since it is felt that pleural infection following wounds depends upon the presence of pleural fluid and that a clearer picture of the etiology and treatment can be presented through this limitation.

The cases have been classified into four groups: simple hemothorax, clotted hemothorax, infected hemothorax, and empyema. The use of the term infected hemothorax might be disputed, but it is felt that infected hemothorax may be differentiated from empyema clinically. The patients with infected hemothorax are not generally so ill as those with empyema; the sanguineous nature of the intrapleural fluid may readily be recognized in contrast to the frank pus of empyema; the results of treatment by aspiration and decortication are more satisfactory than in empyema. It is recognized that post-traumatic empyema usually develops from infected hemothorax. Necrotic, fibrinous clots are generally found in the pleural cavity in empyema cases. Thomas and Cleland[8] have pointed out that bacteria may not be cultured from some infected hemothoraces since sterile pockets may be the source of the material examined. In this study bacteria were cultured from all cases regarded as infected hemothoraces.

ETIOLOGY

A number of questions are often asked by medical corps officers of surgeons working in thoracic centers regarding the etiological factors in the development of clotted hemothorax and empyema. In the following paragraphs, data are presented in answer to these questions.

A frequent query is that regarding the time between injury and admission to the center. The average elapsed times from injury to admission are given in Table I. Patients with simple hemothoraces took an average of 21.1 days from injury to admission, while those with empyema took 44.9 days. The

Read, by title, at the Twenty-sixth Annual Meeting of The American Association for Thoracic Surgery, Detroit, Mich., May, 29, 30, and 31, 1946.

*140th General Hospital.

TABLE I. TIME INTERVAL FROM WOUNDING TO ADMISSION TO CENTER

DIAGNOSIS	NO. CASES	INTERVAL IN DAYS
Simple hemothorax	57	21.1
Clotted hemothorax	57	27.9
Infected hemothorax	33	26.7
Empyema	82	44.7
Total	229	32.1

difference is somewhat less striking when the patients who had had no surgical treatment for their pleural infection prior to admission are considered. For these forty-three patients, the average interval was 38.3 days. It is likely that the difference in time interval for simple hemothorax and empyema cases is due to the more serious wounds and less favorable condition of the empyema cases, which led to slower transportation and longer retention for treatment en route. The average number of days from injury to admission to the center for clotted and infected hemothoraces were 27.9 and 26.7 respectively.

The data in Table II are those regarding the causative agent of the primary wounds. There are no significant differences in the four groups of cases with regard to the two principal missiles, gunshot and high explosive fragments. The percentage of gunshot wounds ranged from 24.2 to 33.3 per cent, while wounds from high explosive fragments ranged from 61.4 to 75 per cent. A few patients had been stabbed or crushed. Seven empyemas followed pneumonia. While high explosive wounds were slightly more than twice as frequent as gunshot wounds, the figures usually given for war wounds show a much higher proportion due to high explosive fragments. Imes[5] reported 249 high explosive and seventy-eight bullet wounds in a group of abdominal injuries in this war, a ratio of about 4:1.

TABLE II. CAUSATIVE AGENTS OF PRIMARY WOUNDS

DIAGNOSIS	NO. CASES	GUNSHOT	HIGH EXPLOSIVE	STAB	CRUSH	PNEUMONIA
Simple hemothorax	57	19 (33.3%)	36 (64.7%)	1	1	—
Clotted hemothorax	57	19 (33.3%)	35 (61.4%)	2	1	—
Infected hemothorax	33	8 (24.2%)	25 (75.8%)	—	—	—
Empyema	82	24 (32% of 75)	50 (66.6% of 75)	—	1	7
Total	229	70	147	2	3	7

Two problems that are generally associated in inquiring minds regard the results of early open thoracotomy and drainage upon the late results of thoracic wounds. These questions are somewhat difficult to answer by review of the literature, since the surgeons operating in the forward areas[1] have had great difficulties in obtaining adequate follow-up information regarding their patients. The records of all patients were carefully reviewed to determine whether operations of the magnitude of thoracotomy through an enlarged wound or an elective incision had been performed early and whether drainage of the pleural cavity had been provided. Table III lists the types of operations performed in the forward areas. Some of the patients having débridements or no

TABLE III. EARLY OPERATIONS ON CHEST

DIAGNOSIS	NO. CASES	THORACOTOMY	DÉBRIDEMENT	NONE ON CHEST	POSTPNEUMONIC
Simple hemothorax	57	19 (33.3%)	28	10	—
Clotted hemothorax	57	21 (36.8%)	33	3	—
Infected hemothorax	33	11 (33.3%)	19	3	—
Empyema	82	30 (40% of 75)	32	13	7

thoracic operation did have major abdominal operations performed. During débridements no effort had apparently been made to explore the thoracic cavity. In a number of operations listed as thoracotomies extensive exploration of intrapleural lesions would not have been possible, since the incisions and wounds were relatively small. The percentage of thoracotomies in the four groups varied from 33.3 to 40 per cent; the differences are not significant.

Table IV presents data showing that the injured pleural cavities were drained with intercostal tubes in from 15.8 to 33.3 per cent of the cases in the forward areas. Many visitors in the center had asked about the number of patients with clotted hemothorax, whose chests had been drained early. The low figure of 15.8 per cent drainage after early operation is not sufficiently lower than that for the other groups to add much support to a belief that lack of drainage leads to clotted hemothorax. The experience in the center indicates that single intercostal drainage tubes are often ineffective. As a rule, the intercostal drains had been removed in from two to four days following the early operations. In several cases it was thought that too prolonged drainage might have led to intrapleural infection.

TABLE IV. DRAINAGE FOLLOWING PRIMARY OPERATION

DIAGNOSIS	NO. CASES	OPERATION AND DRAIN	OPERATION WITHOUT DRAIN	NO OPERATION ON CHEST	POSTPNEUMONIC
Simple hemothorax	57	14 (24.6%)	33	10	—
Clotted hemothorax	57	9 (15.8%)	45	3	—
Infected hemothorax	33	9 (27.6%)	21	3	—
Empyema	82	25 (33.3% of 75)	37	13	7

It is generally believed that foreign bodies lying in the pleural cavity often are the cause of infection. In this center, foreign bodies larger than one centimeter in diameter were customarily removed, in addition to those associated with pulmonary reaction or lying close to the heart or great vessels. The greater danger of intrapleural foreign bodies as compared with intrapulmonary is apparent from Table V. Ten of each were associated with infected hemothorax

TABLE V. SIGNIFICANT METALLIC FOREIGN BODIES

DIAGNOSIS	NO. CASES	PULMONARY	PLEURAL	MEDIASTINAL	SUBPHRENIC
Simple hemothorax	57	4	3	3	—
Clotted hemothorax	57	7	10	—	1
Infected hemothorax	33	5	5	2	1
Empyema	82	5	5	—	2
Total	229	21	23	5	4
Total significant metallic foreign bodies in 511 cases		72	35	21	9

and empyema, but the percentages of the total number of each were 13.9 for intrapulmonary and 28.6 for intrapleural foreign bodies.

Furthermore, additional study of the infected hemothorax and empyema cases shows that three of the ten intrapulmonary foreign bodies listed in Table V protruded directly into the pleural cavity and a fourth had an associated intrapleural patch of clothing. In three additional patients, rib splinters were found protruding into the pleural cavity in association with bronchopleural fistulas. In two empyemas which followed abdominothoracic wounds, heavy silk sutures were removed from the diaphragm at the time of drainage. If these nine cases are added to the thirty-five with metallic intrapleural foreign bodies, it is seen that of forty-four intrapleural foreign bodies, nineteen (43.2 per cent) were associated with infected hemothorax and empyema. These figures bear out the recognized danger of intrapleural foreign bodies. On the other hand, it is rather surprising to note that thirteen metallic foreign bodies were found in sterile, simple, and clotted hemothoraces. Tuttle, Langston, and Crowley[9] found only one intrapleural foreign body in their group of empyemas, however, and believe their danger more theoretical than real.

The foreign bodies listed in Table V were removed with a few exceptions. One ragged intrapulmonary shell fragment was left in the lung of a patient, who had recovered from an empyema adequately drained at the time of admission; this patient was deaf and dumb following a cerebral embolism. One mediastinal foreign body, probably in the left auricle, was not located at operation. Severe thrombophlebitis involving several major veins contraindicated the removal of a mediastinal foreign body; the patient's infected hemothorax was successfully treated by aspiration. An intrahepatic high explosive fragment remained untouched after the healing of an empyema.

The final consideration in etiology of intrapleural infection deals with the importance of abdominothoracic wounds. Table VI demonstrates the large proportion of empyemas that followed abdominothoracic wounds in contrast to the smaller proportions of simple, clotted, and infected hemothoraces following abdominothoracic wounds. Of the post-traumatic empyema patients, 53.3 per cent had suffered abdominothoracic injuries, while the percentages for the other three groups ranged from 12.3 to 21.2. Furthermore, thirty-three of the forty (82.5 per cent) abdominothoracic wounds in empyema patients had either hepatic or gastrointestinal perforations; in the other three groups only seven of twenty-three (30.4 per cent) abdominothoracic wounds had associated hepatic or gastrointestinal injury. Considered in another manner forty-seven of sixty-three (74.6 per cent) abdominothoracic wounds were followed by infected hemothorax

TABLE VI. ABDOMINOTHORACIC WOUNDS

DIAGNOSIS	NO. CASES	ABDOMINOTHORACIC WOUNDS	HEPATIC WOUND	GASTROINTESTINAL PERFORATION	POST-PNEUMONIC
Simple hemothorax	57	9 (15.8%)	4	0	
Clotted hemothorax	57	7 (12.3%)*	2	1	
Infected hemothorax	33	7 (21.2%)	1	0	
Empyema	82	40 (57.1% of 75)*	18	15†	7

*One kidney wound had clotted hemothorax and four had empyema.
†One patient had liver wound also.

or empyema. These data demonstrate the great significance of severe abdominothoracic wounds, especially when accompanied by hepatic and gastrointestinal injury, in the etiology of intrapleural infection.

An interesting sidelight is afforded by Table VII, which gives the average number of units of penicillin administered to patients from the time of wounding to admission to the center. The data were not complete on all patients, and incomplete figures were not used. The data bear out the importance of the magnitude of the wound in determining the incidence of infection. The larger amounts given patients with infections were in part due to the use of penicillin in treatment of these established infections.

In review, the important factors in the etiology of infection following war wounds of the chest are intrapleural foreign bodies and the severity of the wounds, especially abdominothoracic wounds with gastrointestinal and hepatic perforation. Great importance of delay in admission to a treatment center, the type of missile, the type of early operation, and early drainage of the pleural cavity have not been demonstrated.

TABLE VII. PENICILLIN DOSAGE PRIOR TO ADMISSION TO CENTER

DIAGNOSIS	NO. CASES	INTRAMUSCULAR		INTRATHORACIC	
		NO. CASES	AVERAGE NO. UNITS	NO. CASES	AVERAGE NO. UNITS
Simple hemothorax	57	47	674,000	27	92,000
Clotted hemothorax	57	45	892,000	28	87,100
Infected hemothorax	33	30	1,365,000	14	120,000
Empyema	82	69	1,869,000	40	189,000

DIAGNOSIS AND TREATMENT

Simple Hemothorax.—The diagnosis of simple hemothorax is relatively easy in the presence of the physical and roentgenographic signs of intrapleural fluid in patients who have sustained thoracic wounds. For the diagnosis and localization of the fluid collections, the importance of proper roentgenographic and roentgenoscopic examination cannot be overemphasized. Throughout the work of the center, all lateral roentgenograms were made with the Lysholm grid. Lateral films exposed with ordinary technique were not found adequate. Aspiration of fluid is the final diagnostic measure. Although cultures were not planted from every specimen of fluid aspirated, it is proper that this be done. Only through numerous cultures will all cases of infected hemothorax be recognized.

Simple hemothoraces were treated by repeated aspiration without air replacement until the pleural cavities were dry. Up to 3,000 c.c. of sanguineous fluid were removed from these patients with as many as nine aspirations. While not more than 1,000 c.c. of fluid were usually removed at one time, 2,000 c.c. have been aspirated without ill effects. The young patients were able to make the circulatory adjustments to the removal of large quantities of fluid in a far better manner than older patients of civilian practice.

Penicillin was not routinely placed in the pleural cavities of patients with sterile hemothorax following aspiration. Penicillin should be available for injection whenever aspiration is planned, since the finding of fluid suggestive of

infected hemothorax or empyema is a clear indication for intrapleural injection. Without doubt penicillin should be always placed in the pleural cavities of patients aspirated soon after injury in an effort to prevent infection. In these patients, who reached the center from three to seventy-seven days following injury, in no case did it appear that late infection occurred. Negative cultures were obtained in twenty-nine cases; in the remaining, cultures were not planted.

Clotted Hemothorax.—The diagnosis of clotted hemothorax depends upon the aspiration of amounts of fluid from the pleural cavity, which are far smaller than the physical and roentgenographic signs indicate. At the first aspiration of a clotted hemothorax, a good quantity of fluids may be removed before plugging of the needle occurs. Usually only small quantities of fluid, which may contain minute clots, are obtained. Clear serum, which has been expressed from the clots, is sometimes removed. The roentgenograms may show evidence of loculation with multiple fluid levels (Fig. 15). The roentgenographic picture may simulate chronic empyema with retraction of the mediastinal structures toward the affected side after the aspiration of some fluid. The retraction is due to lack of expansion of the lung, which is compressed by scar tissue.

An effort should be made in cases of clotted hemothorax to attain cure by aspiration and voluntary breathing exercises. With small collections of clotted blood this program is usually successful, as in fifteen cases of this series. After a short experience with attempts at aspiration of larger intrapleural collections of clotted blood, thoracotomy with removal of the clotted blood and the restricting visceral and parietal scar tissue was found to be the treatment of choice. The striking pathologic picture, as seen at operation, of large masses of clotted blood floating in sanguineous or serous fluid and enclosed in a fibrous capsule sometimes over one centimeter in thickness, makes one wonder why aspiration had been used for more than diagnostic purposes.

Thoracotomy was customarily carried out with resection of the sixth or seventh rib and opening of the pleural cavity through the periosteal bed and the scar tissue on the parietal pleura. After evacuation of the fluid and clotted blood and the opening of all pockets, which were usually present, a cleavage plane was established between the scar tissue and the visceral pleura. It was usually possible to begin the dissection of the scar at a free edge or by incising the scar down to the visceral pleura, which remains strikingly normal in appearance. The edges of the scar tissue are then picked up and by blunt dissection the scar is separated from the pleura. It is important that the entire lung be freed to permit normal expansion. On the right a freely and normally expanding middle lobe is quite essential. It is usually necessary to mobilize the entire lung. The scar tissue is then removed from the parietal pleura in order to facilitate normal function of the thoracic wall. Lush and associates[6] state that they did not remove the scar tissue from the parietal pleura, due to excessive bleeding. If the proper cleavage plane is found, the parietal pleura is left in situ and the bleeding is not great. The parietal scar may be very thick up to over 1.5 cm. The diaphragm is then mobilized from the thoracic wall. In freeing the visceral scar, small bronchopleural fistulas may be opened. With proper drainage and postoperative care these are not of serious con-

sequence. In some cases the fistulas were closed with fine atraumatic catgut sutures, but the needles and sutures often caused other fistulas. The final picture of the lung expanding normally with moderate positive pressure is very striking. The term decortication has been introduced to denote the operation described, and will be used in the remainder of the paper.

CASE 1.—Thoracotomy and decortication for clotted hemothorax. P. M., a 24-year-old soldier, sustained a perforating gunshot wound of the right chest Jan. 6, 1945. The wounds were débrided the same day. 980,000 units of penicillin were administered intramuscularly from January 6 to 11, and 450 c.c. of sanguineous fluid were aspirated January 10. The soldier was admitted to the center February 3. The roentgenograms (Figs. 1 and 2) demonstrated a good-sized right pleural effusion. Aspiration on February 3, 4, and 11 removed only small amounts of fluid. A right thoracotomy with removal of a large amount of clotted blood and decortication was performed on February 16. The scar was removed from the visceral and parietal pleuras. Anterior and posterior intercostal drains were placed before closure of the thoracic cavity; they were removed in forty-eight hours. The patient made a complete recovery. The final roentgenogram on March 4 (Fig. 3) showed complete expansion of the lung.

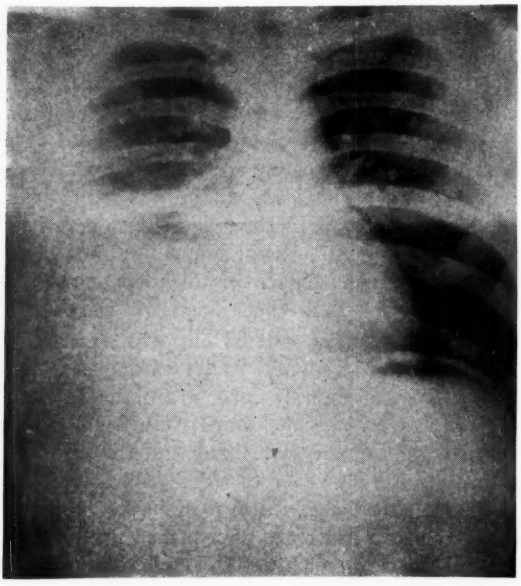

Fig. 1.—Case 1. Posteroanterior roentgenogram of clotted hemothorax.

Two cases of particular interest did not have intrapleural fluid present at the time of admission to the center. In both patients the left lung was collapsed due to bronchopleural fistulas with positive intrapleural pressure. In one patient an attempt had been made to expand the lung by continuous suction through a needle introduced intercostally into the pleural cavity. Further attempts at expansion by repeated aspiration were unsuccessful, due to the large size of the fistulas and ball valve action. In these patients at operation the fibrous scars found compressing the lungs were readily stripped from the

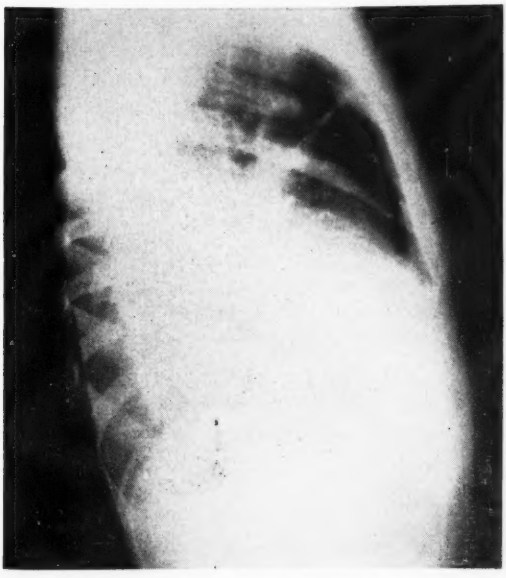

Fig. 2.—Case 1. Right lateral roentgenogram demonstrating the large size of the clotted hemothorax as seen in this projection.

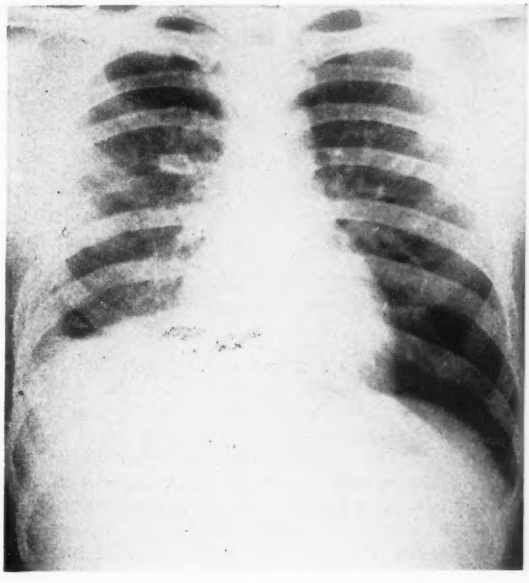

Fig. 3.—Case 1. Posteroanterior roentgenogram sixteen days following decortication.

visceral pleuras. Small partial resections of the lower lobes were necessary to remove the indurated, fibrotic, pulmonary tissue, the site of the fistulas. In only one other patient in the entire group was a partial pulmonary lobectomy necessary.

CASE 2.—Thoracotomy, decortication, and partial lobectomy for collapsed lung and bronchopleural fistula. L. S., a 25-year-old soldier, received a penetrating gunshot wound of the left chest with fracture of the ninth rib Feb. 13, 1945. On the same day a thoracotomy with resection of the fractured rib was performed. 50,000 units of penicillin were placed in the pleural cavity and 40,000 units on February 25 after the aspiration of 400 c.c. of fluid. The first five days following injury, 960,000 units were given intramuscularly. The patient was admitted to the center Feb. 13, 1945, with a totally collapsed left lung (Fig. 4). On five occasions 1,000 c.c. of air were aspirated and slightly negative intrapleural pressures were attained. Fluoroscopy following aspiration demonstrated the lung to be about 40 per cent expanded. On each day following aspiration, however, the collapse was again total. It was apparent that the bronchopleural fistula was preventing the expansion

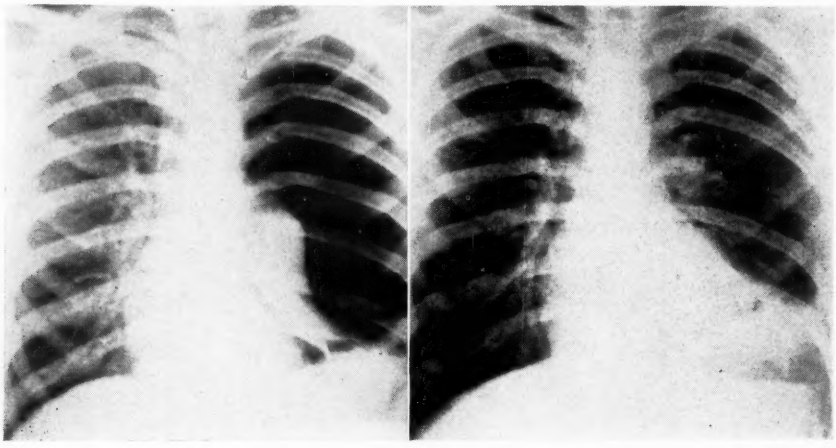

Fig. 4. Fig. 5.

Fig. 4.—Case 2. Posteroanterior roentgenogram of totally collapsed left lung with bronchopleural fistula.

Fig. 5.—Case 2. Posteroanterior roentgenogram showing fully expanded lung after decortication and partial lobectomy.

of the lung, which was restricted with a fibrous scar. A left thoracotomy was performed March 5. The collapsed lung was covered with firm scar tissue 2 to 3 cm. thick, which could readily be stripped free. Only with considerable difficulty was it possible to free the lung from the diaphragm. The bronchial fistula was found in yellow, indurated tissue, which could readily be differentiated from the remaining lung. This small segment was resected and its vessels ligated. The lung was then readily expanded with positive pressure anesthesia. The thoracic wall was closed after the placing of anterior and posterior intercostal drains, which were removed in forty-eight hours. The lung expanded completely as seen in the final roentgenogram April 4 (Fig. 5). The patient returned to the United States on walking status April 9.

In this group of fifty-seven patients with clotted hemothorax, fifteen recovered with aspiration and breathing exercises and forty-two were treated

with decortication. In seven patients, intrapulmonary foreign bodies were removed at the time of decortication and in ten intrapleural foreign bodies; one of the latter patients also had an intrapulmonary foreign body. In a single patient the transdiaphragmatic removal of a subphrenic foreign body was carried out. Sixteen patients were operated upon at another hospital. Two postoperative empyemas and one lung abscess occurred.

At the beginning of the work of the center, the pleural cavity was customarily drained postoperatively with one intercostal drain with water seal. After a short time it was discovered, however, that the use of an additional anterior intercostal tube was of great advantage. A posterior tube alone permitted anterior pocketing of fluid and air. In one patient, an attempt to secure expansion of a lung with secondarily introduced intercostal drains and suction failed, due to a bronchial fistula and the reformation of a constricting scar. An empyema, due to hemolytic *Staphylococcus aureus* and *Escherichia coli*, required rib resection and drainage; at the time of disposition to the United States, only a small tube track remained. Two other patients had their lungs successfully expanded with the use of suction drainage. The experience with the patient developing the empyema led to a more successful treatment of a similar condition in a patient treated at the other hospital. This case demonstrated that secondary decortication is the treatment of choice for an unexpanded lung due to bronchial fistula and restricting scar tissue. Prolonged, unsuccessful suction drainage of such cases can lead only to empyema.

CASE 3.—Secondary decortication. The patient, a prisoner of war, aged about 45, sustained a penetrating shell fragment wound of the right chest Dec. 11, 1944. He was admitted to a station hospital Jan. 12, 1945, with the physical and roentgenographic signs of hemothorax with an intrapleural foreign body (Fig. 6). Aspiration on several occasions removed only small amounts of sanguineous fluid. On January 31, a right thoracotomy and decortication with removal of the large intrapleural shell fragment were performed. The thorax was drained with a posterior intercostal tube. Convalescence was complicated by failure of the lung to re-expand and a bronchopleural fistula. An intercostal tube was inserted again on February 22, and suction drainage of the pleural cavity was instituted. The roentgenographic examination March 4, 1945, demonstrated the unexpanded lung with a restricting pleural scar (Fig. 7). A thoracotomy with decortication was performed March 8. A well-developed, firm scar was removed from the visceral pleura, permitting the lung to expand at once. The thorax was drained with anterior and posterior intercostal tubes, which were removed with the lung expanded within forty-eight hours. The completely re-expanded lung is seen in the roentgenogram May 6 (Fig. 8). The scoliosis present is due to inadequate performance of breathing exercises. The patient was transferred to Germany completely recovered.

Proper placing of the intercostal drainage tubes is of great importance. The anterior tube is introduced just lateral to the costochondral junctions in the fifth interspace and the posterior tube in the ninth or tenth interspace. Unless held against the thoracic wall, the tubes may fall into positions that actually interfere with proper expansion of the lung. A satisfactory method of fixation is accomplished by passing a fine chromic catgut suture through an intercostal muscle from within the chest; the suture is then tied around (not transfixing) the drainage tube, holding the tube against the chest wall. The

tubes may then be shortened and removed as desired. The suggestion of Thomas and Cleland[8] of using suction drainage after twenty-four hours was adopted when necessary.

A second empyema occurred following decortication in a patient whose pleural cavity also contained a good-sized metallic foreign body lying in the clotted blood. Cultures of fluid removed prior to operation had been sterile. Although the cultural findings from the empyema of *Aerobacter aerogenes* and hemolytic *Staph. aureus* suggest an etiologic connection with the foreign body, it seemed likely that the pleural infection was due to necrosis of the skin and subcutaneous tissue about one drainage tube. Too small a skin incision had been made for this tube. The patient made a complete recovery following two rib resections for the pocketed empyema.

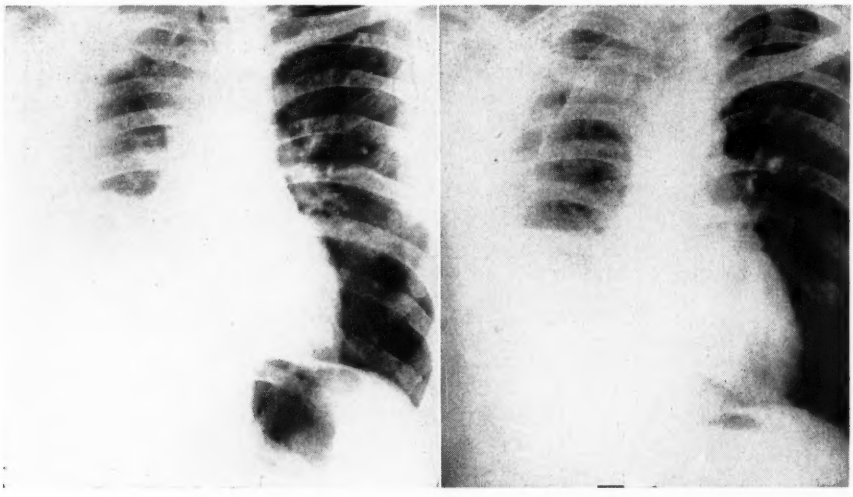

Fig. 6. Fig. 7.

Fig. 6.—Case 3. Posteroanterior roentgenogram of clotted hemothorax.

Fig. 7.—Case 3. Posteroanterior roentgenogram showing the unexpanded right lung with newly formed scar on visceral pleura thirty-two days after decortication; the intercostal tube introduced for suction drainage is shown.

A serious complication occurred in a patient with a small clotted hemothorax and a ragged foreign body lying in the apical segment of the right lower pulmonary lobe. After decortication, the foreign body was removed with some difficulty. A good-sized pulmonary artery was retracted to afford access to the foreign body, which lay unusually deep in the pulmonary tissue. An hemolytic *Staph. aureus* was cultured from the foreign body site. A pulmonary abscess of the affected apical segment developed. The patient was bronchoscoped and 1,360,000 units of penicillin were given intramuscularly from the ninth to the seventeenth postoperative day. The lung abscess entirely regressed, but convulsive seizures and evidence of increased intracranial pressure developed. The patient was transferred to a neurosurgical center. On two occasions

unsuccessful operative attempts were made to locate a brain abscess. The patient was seriously ill when last heard from.

Pathologic examination was made of all tissue removed at operation in the center. In the scar tissue removed from one patient, microscopic tubercles were found, and acid-fast bacilli were demonstrated with appropriate staining. The decortication had been very difficult. There was no history suggestive of tuberculosis obtained from the intelligent patient, who had been wounded by a shell fragment. An excellent result was obtained. No evidence of parenchymal tuberculosis was present in the postoperative roentgenograms. This case is cited in view of the increasing discussion of the applicability of decortication in the treatment of unexpanded lungs due to tuberculous empyema.

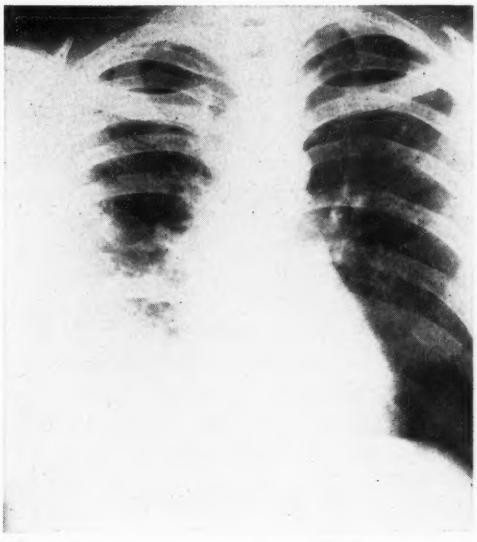

Fig. 8.—Case 3. Posteroanterior roentgenogram showing the fully expanded lung following secondary decortication.

Penicillin was not used postoperatively in cases of sterile clotted hemothorax except in five instances. Technical errors, rather than lack of penicillin, are thought to have been the cause of three of the complications discussed. It may well be urged that penicillin might have prevented the lung abscess if used postoperatively. Thorough decortication, adequate postoperative drainage, and early complete expansion of the lung are regarded as the important factors in obtaining good results.

Infected Hemothorax.—In the center, sixteen patients of thirty-three with infected hemothorax were successfully treated with aspiration alone. In four of the more severe instances, penicillin was used. In five patients the hemothoraces were very small with less than 50 c.c. of fluid being aspirated. The infections in the patients cured by aspiration were not severe, with possibly one exception. This patient, who had a good-sized infected hemothorax and

a ragged mediastinal foreign body, would ordinarily have been subjected to decortication with removal of the foreign body. Two severe episodes of thrombophlebitis intervened, however; in one the right femoral vein and the vena cava were involved, and in the second the left subclavian vein. An operation of any great magnitude was certainly contraindicated. The pleural cavity was aspirated fourteen times before the hemothorax was apparently cured. Penicillin was given intrapleurally and intramuscularly. *Bacillus subtilis, clostridium tetani,* and hemolytic *Staph. aureus* were cultured from the fluid.

Aspiration was not persisted in for patients who were seriously ill from the intrapleural infection. The presence of clots and organisms insensitive to penicillin prevent satisfactory results from aspiration of many patients.

The treatment of the seventeen patients with infected hemothorax treated by drainage (eleven cases) and decortication (six cases) will be included in the discussion of the treatment of empyema.

Empyema.—The eighty-two empyema patients should be divided into two groups. The first group of forty-three patients had received no operative treatment of the empyema prior to admission to the center, while the second group of thirty-nine had either been operated upon for empyema or had draining wounds, the direct result of their injury or following the primary treatment. These thirty-nine patients were admitted with draining sinuses, widely open wounds, or empyemas from which drainage tubes had been prematurely removed. In seven instances further treatment of the adequately drained empyemas other than proper care of the drainage tubes was not required. The remaining thirty-two patients were reoperated upon in the center.

While some success was attained with aspiration in the treatment of infected hemothoraces, no case of empyema was successfully treated with this method alone. One patient was admitted with a drained empyema and an apical pocket containing pus; four previous operations including a decortication for empyema had been performed. The apical pocket was aspirated upon three occasions and 215,000 units of penicillin injected before a cure was attained. The organism cultured from the aspirated pus was *Klebsiella pneumoniae;* a penicillin sensitivity determination was not made.

There were sixty-seven patients with infected hemothorax or empyema treated by rib section and dependent open drainage. In a number of patients, water-seal closed systems were used for some days following operation. Customarily, a perpendicular incision was made, a segment of rib from 10 to 12 cm. long was resected subperiosteally, and a large caliber rubber tube was inserted. The dependent point was determined by injection of iodized oil into the pleural cavity at the time of diagnostic aspiration prior to taking of anteroposterior and lateral roentgenograms (Figs. 17 and 18). In the postoperative care of the cases, the size of the drainage tracks was carefully followed with roentgenographic studies made following injection of iodized oil into the tracks (Figs. 11 and 12). Operative treatment was supplemented by early activity and breathing exercises to restore respiratory function. Blood transfusions were necessary for a good number of patients. All were given adequate diets and supplemental vitamin medication.

The wide open drainage method with multiple tubes advocated by Harken[4] or with packing was not used. While excellent results have been attained by these methods in other hands, they do not seem as satisfactory as a more limited operation at which the pleural cavity may be fully drained and cleared of clots and foreign bodies. A great disadvantage of the long rib resection is the impossibility of later performing a decortication if the lung fails to expand (Case 8). A satisfactory closed drainage system following decortication would be unattainable.

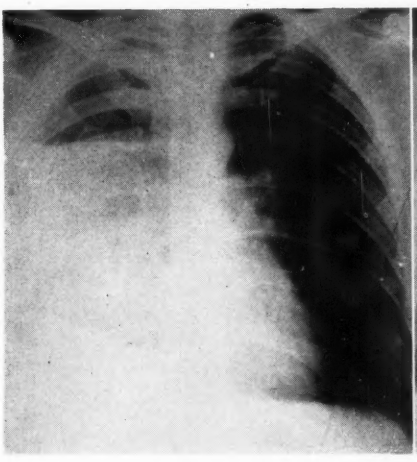

Fig. 9.

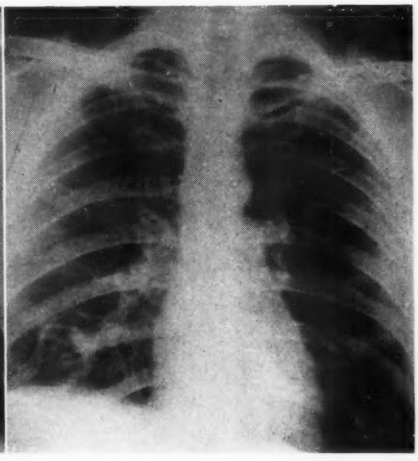

Fig. 10.

Fig. 9.—Case 4. Posteroanterior roentgenogram of massive right empyema.

Fig. 10.—Case 4. Posteroanterior roentgenogram showing completely expanded right lung following open drainage of empyema.

CASE 4.—Open drainage of empyema. H. W., a 37-year-old soldier, received a perforating shell fragment wound of the right chest and abdomen Sept. 19, 1944. Later this same day, a laparotomy was performed and lacerations of the diaphragm, the upper pole of the right kidney, and the hepatic flexure of the colon were repaired. A colostomy was performed. 840,000 units of penicillin were given intramuscularly from September 19 to 22. A severe infection of the abdominal wound occurred, causing it to break down. A secondary closure was performed Oct. 13, 1944, and 2,000 c.c. of sanguineous fluid were aspirated from the right pleural cavity Oct. 7, 1944, and smaller amounts on other occasions. The patient was admitted to the center Oct. 19, 1944. He was seriously ill from a massive empyema (Fig. 9) and an infected abdominal wall wound about the colostomy. An open drainage with rib resection was performed Oct. 21, 1944. A closed drainage system was maintained for several days. November 20, the colostomy was closed after the application of clamps to the spur for several days. The lung expanded completely (Fig. 10). The patient was transferred to the United States completely recovered on April 13, 1945.

The case discussed illustrates the good results attained by open drainage with adequate supportive treatment and breathing exercises. This patient would have been unable to have decortication on admission to the center because of the poor general condition and the colostomy with its extensively infected

surrounding wound. Following the empyema drainage, the condition of the patient improved to permit satisfactory closure of the colostomy.

In several of the patients admitted with previously treated empyemas small unroofing operations were necessary for their cure. These operations were so limited in extent that they are properly considered as open drainages. No extensive open thoracoplasties were necessary.

CASE 5.—Redrainage and unroofing of empyema with bronchopleural fistula. J. W., a 28-year-old officer, was struck with bomb fragments July 28, 1944, sustaining a compound fracture of the skull and a penetrating wound of the abdomen and right thorax. Shortly after injury the head wound was débrided and a laparotomy with suture of the lacerated liver was performed. 440,000 units of penicillin were administered intramuscularly between July 26 and Aug. 7, 1944. An anterior thoracotomy was performed on Aug. 11, 1944, and a shell fragment was removed from the right middle lobe, which was partially resected; a decortication for clotted hemothorax was also carried out. 120,000 units of penicillin were given intravenously August 11, and 1,680,000 units intramuscularly from August 12 to 27.

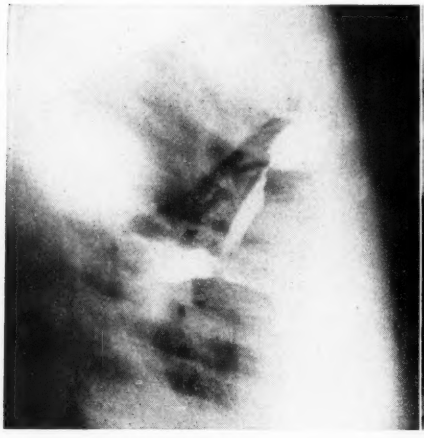

Fig. 11.

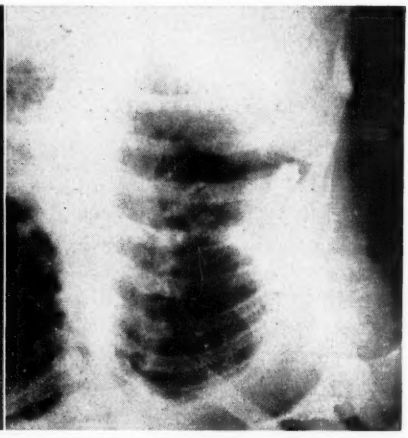

Fig. 12.

Fig. 11.—Case 5. Posteroanterior roentgenogram following the injection of iodized oil into the chronic empyema cavity.

Fig. 12.—Case 5. Right lateral roentgenogram shows the long drainage track, which made cure without operation unlikely.

Intercostal drainage for an empyema which developed was carried out August 30. Anterior and posterior open drainage was instituted September 22. Closed suction drainage systems were installed and breathing exercises were begun.

The patient was admitted to the center Dec. 2, 1944, with the empyema drained with anterior and posterior tubes. The anterior tube was removed. Progress was not satisfactory. Roentgenograms following the injection of iodized oil into the empyema demonstrated a small pocket lying anterolaterally, drained by a long track (Figs. 11, 12). A bronchopleural fistula was present. It was considered that cure without further operation would be unnecessarily long deferred. Jan. 13, 1945, the empyema was exposed by an anterolateral incision. The fifth and sixth ribs were resected and the pleural scar, which was 1.5 cm. thick, was entirely excised over the pocket. The empyema closed rapidly and the patient (Fig. 13) was transferred to the United States March 31. He was retired from the army and returned to his civilian occupation of clergyman during the summer of 1945.

The case illustrates one of the problems of chronic empyema and the good results obtainable by open drainage with complete excision of the pleural scar.

Eleven of the sixty-seven patients whose pleural infections were drained in the center required reoperation. Four were among the patients primarily treated for infected hemothorax or empyema in the center and seven among those treated elsewhere first. In six of these last seven patients, small unroofing operations were performed with good results. At the time of the closing of the center, twenty-one patients were transferred to the United States with draining tracks. Only one of these residual empyemas was large. A decortication would have been advisable had not the patient been slowly recovering following the excision of a brain abscess. At least one redrainage was performed in this group after return to the United States. Complete follow-up information is not available regarding these patients, but several are known to have recovered without further operation.

Fig. 13.—Case 5. The patient, following small unroofing operation for chronic empyema.

Bronchopleural fistulas were present in seventeen patients with infected hemothorax and empyema. The only two bronchopleural fistulas occurring in patients without pleural infection have been already described. As a rule the fistulas closed following adequate drainage. In five patients, muscle plastic operations were completely successful in closing fistulas. In two cases, rib fragments were found embedded at the site of the fistulas when the plastic operations were performed, and in another silk sutures were found. One bronchial fistula was closed with fine catgut sutures at the time of decortication. Only two patients left the center with open bronchopleural fistulas, one of which was closed with a plastic operation in the United States.

Subphrenic abscesses were present in four patients with empyema. There were five liver abscesses, one in a patient with infected hemothorax and four in patients with empyema. In two patients all three lesions were present. The subphrenic and liver abscess were either drained separately or with the pleural

infections as was indicated in each case. All but one were healed at the time of transfer to the United States.

Two patients were admitted with entirely unroofed empyemas and exposed visceral pleura. After improvement in the general condition of these patients and resection of necrotic bone and cartilage in one, the open wounds were closed with mobilization of soft tissues with excellent results. An additional patient was admitted with a diaphragmatic hernia, a perforation of the stomach, and a multilocular empyema following a crushing injury of the thorax. At operation the hernia was repaired, the spleen removed, the gastric perforation closed, and the empyema drained. The patient made a satisfactory recovery although a secondary drainage was necessary, at which some of the silk sutures placed in the diaphragm were removed.

One death occurred among the patients treated by open drainage. It was attributable to renal disease secondary to infection and necrosis in the inadequately débrided muscle tissue of the thoracic wall wound. There was one death also among thirty-two patients treated for empyema at another hospital. The second patient, who was very debilitated due to a long-standing massive empyema, died following open drainage and packing.

CASE 6.—Open drainage and packing of empyema; death due to renal disease secondary to infection and muscle necrosis. R. W., a 20-year-old man, sustained a perforating machine-gun bullet wound of the left thorax April 8, 1945. The fourth and fifth left ribs were fractured in the axillary region. The wound was débrided and an intercostal drain was introduced into the left pleural cavity. 360,000 units of penicillin were given intramuscularly from April 10 to 13, and 420,000 units from April 19 to 24. The patient was admitted April 24 severely ill with an infected edematous wound in the axillary region. Under sodium pentothal anesthesia the wound was opened. Although little pus was present, the latissimus dorsi muscle was nonviable and required removal in this region. The ragged, shattered fourth and fifth ribs were resected, and an opening was made into the moderate-sized empyema, which was packed open after resection of the sixth rib.

Following operation the patient, who was slightly edematous on admission, gradually became more so. The scant urine, which amounted to only 250 to 600 c.c. a day, in spite of adequate fluid intake, contained many red blood cells and large amounts of albumin. Nitrogen retention progressively increased. 1,420,000 units of penicillin were given intramuscularly along with several blood transfusions. The organisms cultured from the wound were *A. aerogenes* and hemolytic *Staph. aureus*. The patient died May 3, 1945. Pathologic examination of the tissue removed at operation showed degeneration of striated muscle.

Although the results of open drainage in the treatment of infected hemothorax and empyema are good, decortication has advantages in some cases. The good results of decortication for clotted hemothorax and favorable reports from other thoracic surgeons led to its use in pleural infections.

While only six patients with infected hemothorax were treated by decortication, it is felt that this method is the treatment of choice in all such cases unless their general condition is very poor or the size of the hemothorax is less than 500 c.c. In empyema, the indications are large multilocular empyemas, depression of the apex of the lung, which makes adequate re-expansion unlikely, the presence of intrathoracic foreign bodies, whose removal would be impossible without major thoracotomy, and the failure of open drainage. The principal contraindications are small size of the pleural collection of fluid, poor general

condition of the patient, thin pus without restricting scar tissue, and widely open thoracic walls, whose airtight closure would be impossible. It should be remembered that open drainage is a method which may be carried out with local anesthesia, while decortication should be done only by a competent surgical team including a trained anesthetist.

The technique of decortication for infected hemothorax and empyema does not differ from that used for clotted hemothorax. It is important that all lobes of the lung be mobilized to permit normal expansion of the lung. Metallic foreign bodies, clothing, and rib fragments must not be overlooked. In this group of patients, ten metallic foreign bodies were removed from the lung and pleura at the time of decortication and one during a preliminary open drainage. In one patient an indurated focus was felt in the lung; when it was opened a piece of clothing was removed, which would never have been accessible or recognized during a drainage operation. Experience demonstrated the value of using three intercostal water-seal tubes to insure adequate postoperative drainage. The third tube was placed in the axillary region.

While penicillin was not customarily employed with uninfected cases, its use in operations for pleural infections is wise, if only to aid primary healing of the operation wounds. Prior to thoracotomy, 100,000 units of penicillin were injected into the pleural cavity on two occasions. After operation, 40,000 units of penicillin were given intramuscularly for ninety-six hours. Complete decortication and adequate drainage to promote expansion of the lung cannot be neglected in spite of penicillin therapy.

Six patients with infected hemothorax and eleven with empyema were treated with primary decortication. Five empyema patients had open drainage prior to decortication. In eleven patients treated with primary decortication, complete healing and re-expansion of the lung was attained at the time of removal of the intercostal drains three days postoperatively. In cases of primary decortication and in the five with preliminary open drainage, more prolonged drainage, or small revision drainage operations were necessary for basilar pockets. These results are regarded as highly successful. Burford and associates had similar results.

There were two unsuccessful results of primary decortication. The operation failed in one patient with a massive, multilocular empyema (*Clostridium welchii*) because only a single, posteriorly placed intercostal tube was used. After open drainage a secondary decortication was performed, three intercostal tubes were placed, and the patient left the center with a track of 55 c.c. capacity. A second failure was due to the poor general condition of the patient and inadequate drainage. This soldier was admitted with a massive empyema (*Cl. welchii*) and a colostomy following a self-inflicted gunshot wound of the chest and abdomen. Although the early result was apparently good, lateral pocketing occurred, which might have been prevented by the use of a third intercostal tube in addition to the two placed. Suction drainage was unsuccessful, due to leakage of air about the tubes in the thin thoracic wall of the debilitated patient. This soldier returned to the United States with a good-sized empyema, which is said to have healed, according to the last information received. In

this case an open drainage and colostomy closure should have preceded the decortication. A similar policy in other patients attained excellent results.

The problems associated with decortication for infected hemothorax and empyema are best demonstrated by illustrative cases.

CASE 7.—Primary decortication for infected hemothorax. J. L. P., a 26-year-old officer, sustained a perforating gunshot wound of the left chest and abdomen Feb. 25, 1945. The following day thoracotomy and laparotomy were performed, with suture of the diaphragm and removal of the injured spleen; an intercostal drain was inserted. 2,780,000 units of penicillin were given intramuscularly February 26 to March 8. The left pleural cavity was aspirated March 8, 19, and 23. The patient was seen in consultation at another hospital March 29, 500 c.c. of sanguineous fluid were aspirated, and 40,000 units of penicillin were introduced into the left pleural cavity. The patient was admitted to the center March 31.

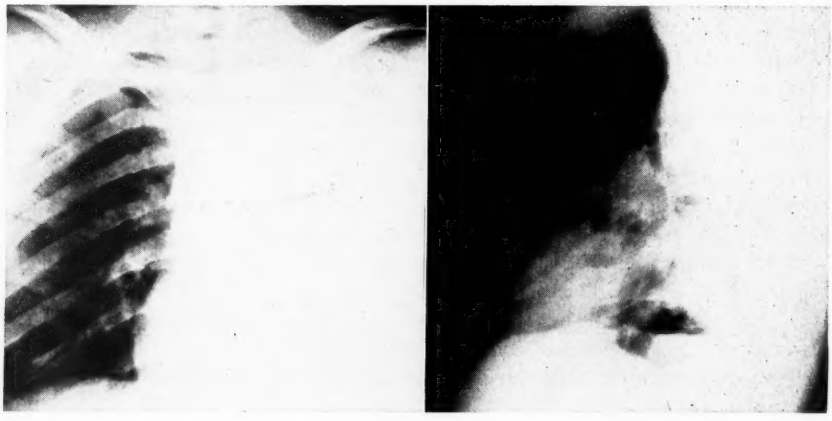

Fig. 14. Fig. 15.

Fig. 14.—Case 7. Posteroanterior roentgenogram showing massive infected hemothorax.
Fig. 15.—Case 7. Left lateral roentgenogram demonstrating the several fluid levels.

Roentgenograms (Figs. 14 and 15) demonstrated a large multilocular fluid collection. Prior to decortication April 4, 40,000 units of penicillin were again given intrapleurally. At operation, large quantities of foul-smelling sanguineous fluid and clots were removed and the thick scar tissue removed from the visceral and parietal pleurae before the lung could be completely mobilized. The left hemothorax was drained with three intercostal tubes placed anteriorly, laterally, and posteriorly. The postoperative course was without event and the lung expanded completely. All the drains were removed in three days. The organisms cultured from the fluid were *Streptococcus viridans*, nonhemolytic *Staph. aureus*, and hemolytic *Staph. aureus*. The latter organism was sensitive to penicillin. 720,000 units of penicillin were given intramuscularly from April 4 to 7. The final roentgenographic result, May 12, is shown in Fig. 16.

The foregoing case demonstrates the good results attainable with decortication for infected hemothorax. The multilocular, massive, fluid collection could have been treated with difficulty with drainage alone.

CASE 8.—Open drainage of empyema followed by decortication. J. M., a 23-year-old soldier, was struck on the posterior right chest by a bullet, which then passed through the left chest fracturing the seventh rib Dec. 21, 1944. The wounds were débrided that day.

500,000 units of penicillin were given intramuscularly December 21 to 26. 500 c.c. meters of fluid were aspirated December 26 and 775 c.c. on Jan. 4, 1945; at this latter aspiration 50,000 units of penicillin were given intrapleurally. The patient was admitted to the center January 23 with the physical signs of a massive left empyema. He was quite ill and had lost considerable weight. 550 c.c. of thick pus were aspirated from the left pleural cavity; 60,000 units of penicillin and 20 c.c. of iodized oil were introduced. Roentgenograms on January 24 (Figs. 17, 18) demonstrated the empyema with the iodized oil lying inferiorly and posteriorly and the fractured seventh rib. Open drainage with resection of the tenth rib was carried out January 25, and a closed water-seal system was established. An hemolytic *Staph. aureus* was cultured from the pus. Although the closed drainage system remained airtight, re-examination February 2 (Fig. 19) showed the lung to be unexpanded due to a thick scar on the visceral pleura. Decortication, which alone would have prevented a massive

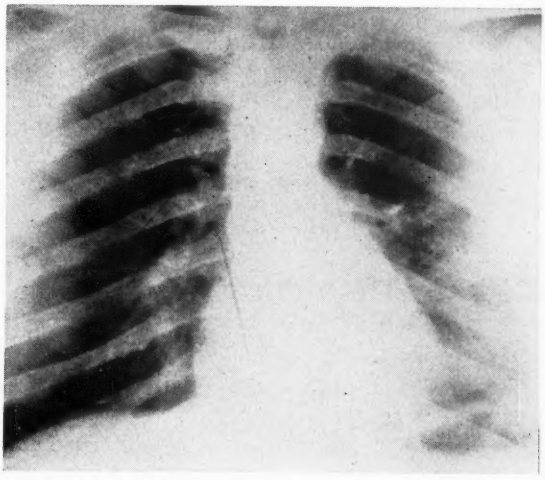

Fig. 16.—Case 7. Posteroanterior roentgenogram showing completely expanded lung following decortication.

chronic empyema, was carried out February 6. The pleural scar was readily stripped from both the visceral and parietal pleurae. The lung could then be readily expanded with positive pressure. The open granulating wound on the back was excised and closed with the thoracotomy incision and airtight drainage was established with a large rubber tube in the old drainage site. 740,000 units of penicillin were given intramuscularly February 5 to 10. The lung was expanded with difficulty since the single drainage tube was cut off from the anterior portion of the pleural cavity when the lung expanded posteriorly. Repeated aspiration of air was successful in achieving expansion. A further complication was caused by the too early removal of the water seal, which permitted the lung to collapse. Suction drainage readily brought about re-expansion of the lung, which was no longer restricted by scar tissue. The thoracotomy wound healed primarily but the secondarily closed wound of entry failed of cure. An extensive undercutting and closure was successful May 11. The final roentgenogram May 19 (Fig. 20) shows the completely expanded lung.

This case demonstrates the value of rib resection of moderate length and closed drainage. Had a long segment of rib been removed for drainage, a satisfactory closed system would not have been possible following the decortication. In addition, the inadequacy of a single drainage tube following

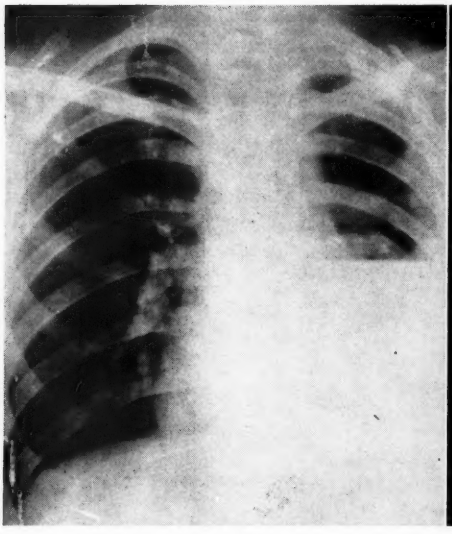

Fig. 17.

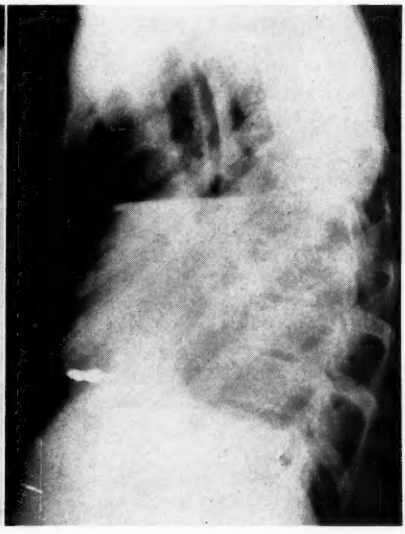

Fig. 18.

Fig. 17.—Case 8. Posteroanterior roentgenogram of massive left empyema. Fractured seventh rib and the iodized oil injected to determine base of empyema are seen.

Fig. 18.—Case 8. Left lateral roentgenogram of massive empyema showing iodized oil at base.

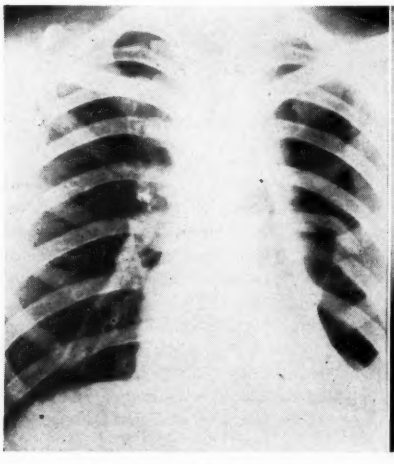

Fig. 19.

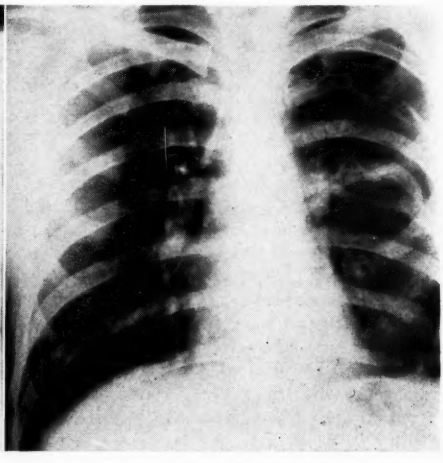

Fig. 20.

Fig. 19.—Case 8. Posteroanterior roentgenogram showing unexpanded lung with dense restricting scar on visceral pleura eight days after open drainage and use of closed water-seal drainage system.

Fig. 20.—Case 8. Posteroanterior roentgenogram showing completely expanded left lung following decortication.

decortication is shown. The lesson of too early conversion to open drainage was fortunately not too costly since suction drainage of the unrestricted lung was successful in achieving re-expansion.

CASE 9.—Primary decortication for empyema necessitatis. B. H., a 20-year-old soldier, received a perforating shell fragment wound of the right chest and abdomen April 16, 1945. The missile passed through the thorax anteriorly, lacerated the diaphragm and liver, and lodged in the back. April 17, the wound of entry was débrided, a thoracotomy with suture of the diaphragm was performed, and the missile was removed from the back. 460,000 units of penicillin were given intramuscularly April 17 to 21 and 100,000 units intrapleurally April 17. 300 c.c. of serous fluid were aspirated from the pleural cavity April 24. The patient was admitted to the center May 1. Physical and roentgenographic signs of a large pleural effusion were present (Fig. 21). A draining sinus track was present at the site of the wound of entry anteriorly. 60 c.c. of foul-smelling blood were aspirated May 2, and 40,000 units of penicillin were introduced. On May 6, only 30 c.c. of pus could be aspirated

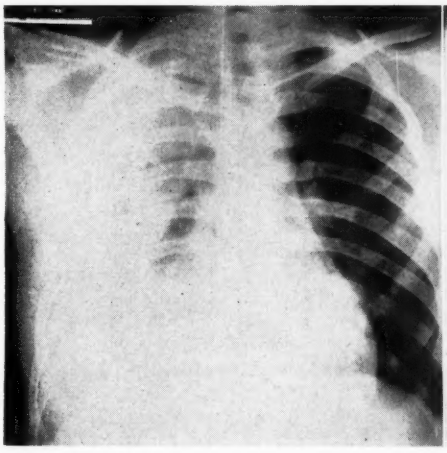

Fig. 21.

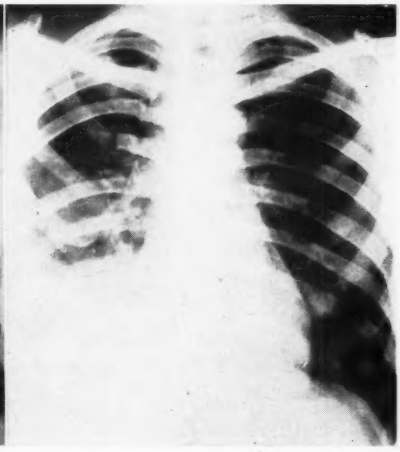

Fig. 22.

Fig. 21.—Case 9. Anteroposterior roentgenogram demonstrating massive right empyema with several pockets.

Fig. 22.—Case 9. Posteroanterior roentgenogram showing fully expanded lung thirteen days after decortication for empyema necessitatis.

and 30,000 units of penicillin were introduced. *Cl. welchii* was cultured from the fluid. A thoracotomy was performed May 7, with excision of the draining wound anteriorly and resection of osteomyelitic rib at this point. A multilocular empyema was found. The thick scar tissue was separated only with difficulty from the pleurae. The pleural cavity was drained with three tubes. Two were removed on the second postoperative day and the remaining one on the third. 600,000 units of penicillin were given intramuscularly May 10 to 13. A slight wound infection occurred. The completely expanded lung is shown in Fig. 22, thirteen days after operation. The patient is seen in Fig. 23, fourteen days after operation. He was transferred to the United States as a walking patient on June 2.

The result in the last case demonstrates the striking values of decortication in multilocular empyema of a severe type. It was possible to excise and close a draining sinus track as part of the thoracotomy wound and still have only a minor wound infection.

CASE 10. Decortication for sterilized empyema. R. M., a 20-year-old soldier, received a perforating shell fragment wound of the left thorax Feb. 9, 1945. The following day an exploratory laparotomy was performed. 2,640,000 units of penicillin were given intramuscularly from February 21 to March 3. In all, 630,000 units were given intrapleurally from April 20 to May 7. The left pleural cavity was aspirated thirteen times between February 13 and April 13, with from 30 to 1,800 c.c. of fluid being removed. A staphylococcus was cultured prior to admission to the center May 2, but succeeding cultures at the center were negative. The patient's general condition upon admission was good, and a large empyema with intrapleural foreign body was present. A decortication and removal of the foreign body was performed May 8. The pleural cavity contained frank pus and a dense scar was stripped from the pleurae only with difficulty. Three intercostal drains were used. The lung expanded completely after suction drainage was instituted on the day following operation. The patient was transferred to the United States walking on June 2.

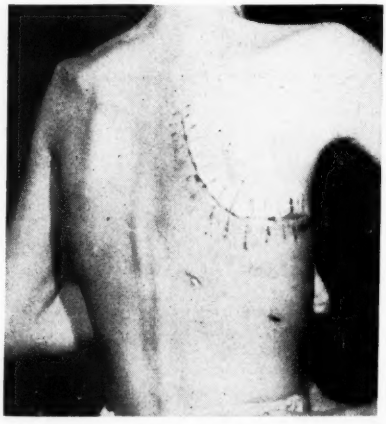

Fig. 23.—Case 9. The patient fourteen days after decortication for empyema necessitatis. The posterior and lateral intercostal drainage sites may be seen.

The case just described is the type reported by Blades, Hamilton, and Dugan.[2] Extensive use of penicillin and aspiration has failed to cure the empyema even though it had become sterile. Cure by drainage of this chronic empyema would have been, at the best, very slow, due to the thick scar compressing the lung. Decortication should be seriously considered in the treatment of all such cases unless they are small.

BACTERIOLOGY

The bacteriologic findings in the infected hemothoraces and empyemas varied from case to case. In all, twenty different organisms were cultured. As many as four different organisms were isolated in one case. It is interesting that pneumococci were found on only two occasions (types 23 and 29). *Cl. welchii* was found thirteen times. A detailed discussion of the bacteriologic findings would be quite complicated. The frequent occurrence of gram-negative organisms such as *B. subtilis*, *Pseudomonas aeruginosa*, *Bacillus proteus*, and *Esch. coli*, along with gram-positive organisms which were insensitive to penicillin, should evoke some caution in evaluating the place of penicillin in the control of established pleural infections.

BREATHING EXERCISES

Any discussion of thoracic wounds and their sequellae would be incomplete without mention of breathing exercises. The British thoracic surgeons have been using voluntary respiratory exercises in their work for a number of years. There is no single measure more valuable in the physical and mental rehabilitation of patients after thoracic wounds and operations than these exercises, which depend upon voluntary, unilateral, controlled breathing. The human race has allowed breathing to become a largely automatic and bilateral function. By recapturing the ability to expand the affected hemothorax alone, the patient can exercise this side and bring it to function normally. Calesthenics and the ordinary breathing exercises develop the unaffected side to the detriment of the injured one.

Miss Reed[7] has described clearly the English methods and Harken[4] has emphasized their importance in the treatment of thoracic wounds. A most gratifying part of the work of a thoracic center has been the excellent condition of the patients at the time of their release. The patients readily caught the importance of breathing exercises in their own rehabilitation. The thoracic patient today should feel that he does not face the world as a partial cripple but that he is as well and fit as if he had had no wound or disease.

SUMMARY

229 patients were admitted to a thoracic center in England with intrapleural fluid or drained empyemas. The cases were classified as simple hemothorax, clotted hemothorax, infected hemothorax, and empyema. The presence of intrapleural foreign bodies and the severity of the initial wound, especially abdominothoracic wounds with gastrointestinal and hepatic injuries, are the two most important factors in the etiology of post-traumatic pleural infection.

Simple hemothorax is treated by repeated aspiration to dryness without air replacement. If clotted hemothorax does not respond to aspiration and breathing exercises, thoracotomy and decortication are the proper treatment. Adequate, dependent open drainage remains the most important method of treatment of infected hemothorax and empyema. Decortication is an operation of great value, however, in the treatment of these conditions with proper indications and with suitable surgical personnel.

Voluntary respiratory exercises, which are combined with early ambulation and proper general care, are an essential part of the rehabilitation of thoracic casualties. The thoracic patient should leave the hospital embued with the feeling of complete physical recovery.

The bacteriologic findings in the pleural infections were extremely varied. Different combinations of twenty organisms were present in the cases studied. Many of the organisms isolated were not sensitive to penicillin.

The authors wish to express their appreciation of the efforts of Maj. Lawrence J. Schuhmacher, Jr., Chief of the Anesthesia Section, 140th General Hospital. His skill and that of his staff made the work of the center possible.

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PULMONARY CYSTS

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PULMONARY cysts comprise one of the most interesting of the abnormalities which may involve the tissue of the lungs. They are of special interest because of the great variation in symptoms that they present and the difficulty that is experienced at times in their differential diagnosis. Therapeutically they are of importance, as proper surgical intervention invariably is followed by gratifying results.

In this presentation, the term "pulmonary cyst" is used to indicate all those abnormalities of the pulmonary tissue in which cysts or cystlike structures of the lungs or bronchi are found, regardless of their pathogenesis, exclusive of such specific entities as tuberculous cavities, parasitic or hydatid cysts, carcinoma of the lung that has undergone cavitation, and ordinary pulmonary abscesses. Cysts of the mediastinum, such as dermoids and teratomas, and mediastinal cysts of bronchiogenic or enteric origin, are not included.

Various authors, such as Koontz,[1] Peirce and Dirkse,[2] Sellors,[3] Maier and Haight,[4] Willis and Almeyda,[5] Anspach and Wolman,[6] Dickson,[7] and Adams and Castleman,[8] have attempted with varying degrees of success to subdivide cystic disease of the lung into distinct classifications based on origin, location, size, and pathologic characteristics. Essentially, all pulmonary cysts can be divided into two chief types: those that originate from the bronchial tree and those that are alveolar in origin.

This presentation is primarily concerned with those cysts that are of bronchiogenic origin. Bronchiogenic cysts are characterized by the fact that they possess an epithelial lining consisting of columnar or cuboidal cells which may or may not be ciliated. This lining may be smooth and regular, or roughened, irregular, and trabeculated. The walls of the cyst contain most, if not all, of the bronchial elements, but as Sellors has pointed out, the cartilage, smooth muscle, elastic tissue, and mucous glands are not in an orderly arrangement as might be expected in a dilated bronchus. The cysts may contain fluid, pus, blood, or air, alone or in combination, and may be in direct communication with the bronchial tree.

In contrast, those cysts which are alveolar in type do not possess an epithelial lining but are lined by alveolar cells that are compressed together to form the wall. In addition, they always contain air.

There is considerable speculation whether pulmonary cysts are congenital or acquired. Unfortunately, it is difficult to determine this point even after thorough microscopic examination. In fact, it is likely that many acquired factors influence the so-called congenital or developmental cysts, so that the

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end results seen at operation later in life or on gross examination of the post-mortem specimen are far different from the original developmental or so-called congenital defect at the time of its inception. In our present stage of knowledge we are certainly not prepared to state whether or not a small actual or potential cyst, which at some later time will become larger and detectable clinically, may be congenital or developmental. (Much emphasis has been placed on the presence or absence of pigment in the wall of the cyst as a criterion for determining the congenital or acquired nature of the cyst. Dickson has demonstrated that this feature cannot be relied on as a basis of differentiation.) From our observation we are of the opinion that pulmonary cysts may be acquired as well as congenital.

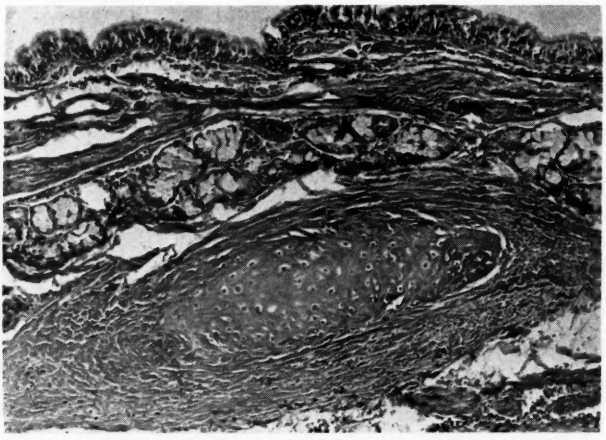

Fig. 1.—Lining of bronchiogenic cyst (×85).

The present study is based on a review of forty-four cases of pulmonary cyst of the bronchiogenic type seen at the Mayo Clinic during the last ten years, in which the diagnosis was confirmed by surgical exploration and removal of the cyst, or of tissue from the cyst, for microscopic examination. Cysts of the mediastinum, even though of bronchiogenic origin, were not included in this study.

The cases were divided into three groups. The first group consisted of twenty-seven cases in which the cysts possessed all of the characteristic microscopic evidence of bronchiogenic cysts (Fig. 1). The second group was made up of nine cases, in all of which the cysts had the gross appearance of bronchiogenic cysts, but on microscopic examination of the cyst wall there was found to be an absence of an epithelial lining and partial or complete absence of bronchial elements in the wall. The wall of the cyst was usually composed of fibrous connective tissue. It is suspected that these are very likely bronchiogenic cysts in which the wall has been altered by pressure or by infection (Fig. 2). The third group consisted of eight cases in which there was a cystic

dilatation of the bronchi of a greater diameter than 3 cm. These cases are classified as cystic bronchiectasis. There may well be some question as to the justification of including these patients along with the two preceding groups in the study, but they have been included because of their possible relationship and the aid they may offer in the better understanding of the development of bronchiogenic cysts.

Fig. 2.—Lining of cysts included in group 2 (×65).

The entire group of forty-four patients included twenty-four males and twenty females. The youngest patient was 7 years of age and the oldest, 58. The average age was 30 years. The cysts were found to occupy every portion of the lung. The right side was more frequently involved than the left in a proportion of twenty-eight to sixteen. The distribution according to lobe is indicated in Table I. As Harrington[9] has pointed out, cystic changes are a

TABLE I. DISTRIBUTION OF PULMONARY CYSTS ACCORDING TO LOBE IN FORTY-FOUR CASES

LOBE	NO.
Right lower	14
Right upper	9
Left upper	8
Left lower	4
Multiple lobes	4
Azygos lobe	3
Middle lobe	2
Total	44

rather frequent occurrence in aberrant or accessory pulmonary tissue. In all eight of the cases of cystic bronchiectasis the cysts were multiple. The cysts were solitary in thirty-two of the remaining cases, and multiple in four.

SYMPTOMATOLOGY

Pulmonary cysts are characterized by their variability in producing symptoms. Those cysts in which there is not a communication between the cyst and the bronchial tree are less likely to give rise to symptoms than those in which such a communication exists, although the latter may also remain clinically dormant for an indefinite period. The status of the bronchial communication, its ability to permit air to enter and leave the cyst, and the presence of infection are prime factors leading to the production of symptoms. Secondary pulmonary infection such as bronchiectasis, which is frequently found associated with pulmonary cysts, may alter somewhat the character of the symptoms. The frequency with which symptoms were encountered in the present study is given in Table II.

TABLE II. FREQUENCY OF SYMPTOMS IN FORTY-FOUR CASES OF PULMONARY CYST

SYMPTOM	BRONCHIOGENIC CYST (27 CASES)	INDETERMINATE TYPE OF PULMONARY CYST, PROBABLY BRONCHIOGENIC (9 CASES)	CYSTIC BRONCHIECTASIS (8 CASES)
Cough	19	4	8
Expectoration	12	2	6
Hemoptysis	10	4	7
Dyspnea	10	1	2
Pain	9	3	3
Fever	7	3	2
Weakness	3	1	0
Weight loss	2	1	1
Dysphagia	1	0	0
Stridor	2	0	0
Palpitation	0	0	0
No symptoms	3	4	0

Cough and expectoration were the most prevalent symptoms observed, and usually made their initial appearance following an acute respiratory infection. Eloesser[10] has stated that "a long story of continued cough and expectoration dating from childhood with signs of bronchial suppuration but with no demonstrable etiology should arouse suspicion of congenital cystic disease in an adult." In many instances cough and expectoration do not make their appearance until later in life. Hemoptysis was a common symptom and varied in intensity from streaking of the sputum with blood to exsanguinating hemorrhages. When the bleeding was severe there was a tendency for it to last several days up to a week or more. It was not uncommon to find the cyst filled with blood and blood clots at the time of operative removal. Pain was frequently noted and varied greatly in character but was generally described as a sense of substernal soreness. At times it was excruciating, requiring narcotics for relief. Dyspnea, as Wood[11] has emphasized, is a frequent accompaniment of pulmonary cyst and should always arouse the suspicion of its presence.

Intermittent attacks of fever, either with or without chill, were often present. They usually occurred after acute respiratory infections. It was not uncommon for such episodes to be diagnosed erroneously as pneumonia. There was great variability in the duration of symptoms. In some cases the history dated back but a few months, while in others the trouble had been noted since childhood. The following report is rather typical of the picture seen in cases of pulmonary cyst.

CASE 1.—The patient was a woman 35 years of age. She had been perfectly well until six years previous to our examination when, following an acute respiratory infection, fever and cough had developed. A diagnosis of pneumonia had been made. Since then, she had had a constant cough with expectoration of purulent material, which at times was blood streaked. Frequent respiratory infections developed, during which periods her symptoms would become more pronounced and she would expectorate large amounts of purulent material, especially with change of position. She had been kept in bed for ten months as a patient with suspected pulmonary tuberculosis.

Roentgenograms of the thorax at the time of admission to the Mayo Clinic showed a shadow in the right midlung field which was thought to be a pulmonary cyst. The right lower lobe, containing the cyst, was removed. The cyst was found to be of bronchiogenic type.

Cases 2 and 3 are examples of the type of pulmonary cyst that has been included in the present study:

CASE 2.—The patient was a man, 27 years of age. At the age of 6 years he had had what was diagnosed as pneumonia, and since then he had been subject to frequent colds. During the nine years preceding admission he had had attacks of chills and fever associated with his colds. Although he had a chronic cough, there had been very little expectoration. During this time he had had recurrent attacks of hemoptysis.

At the time of examination at the Mayo Clinic, the roentgenogram of the thorax showed a pulmonary cyst involving the right upper lobe (Fig. 3*a*). At operation, a large cyst arising from the right upper lobe was found. Pneumonectomy was performed, and the cyst was found to be of bronchiogenic type (Fig. 3*b*).

The following case had many of the roentgenologic characteristics of the so-called balloon type of cyst, which is usually alveolar in origin.

CASE 3.—The patient was a boy 7 years of age. During the three years prior to admission he had had intermittent attacks of fever with elevation of temperature to 103° and 104° F. These attacks had been diagnosed as pneumonia.

Roentgenographic examination of the thorax at the time of our examination showed a large cyst in the left upper lobe measuring 8 cm. in diameter, with a small amount of fluid in its base (Fig. 4*a*). At operation, a large cyst was found involving the left upper lobe. Left upper lobectomy was performed. The gross specimen is shown in Fig. 4*b*. This cyst was lined by flat cells of an indeterminate type, not of bronchial type. Inflammation was present throughout the wall of the cyst. A very small amount of lymphoid tissue was present. The greater portion of the wall was made up of fibrous connective tissue.

This case is one example of pulmonary cyst classified as the indeterminate type. The patient was the youngest in the group of patients studied.

In seven of the cases of pulmonary cyst in the present study, there were no pulmonary symptoms. Cases 4 and 5 are in this group and illustrate respectively cysts of bronchiogenic and indeterminate type.

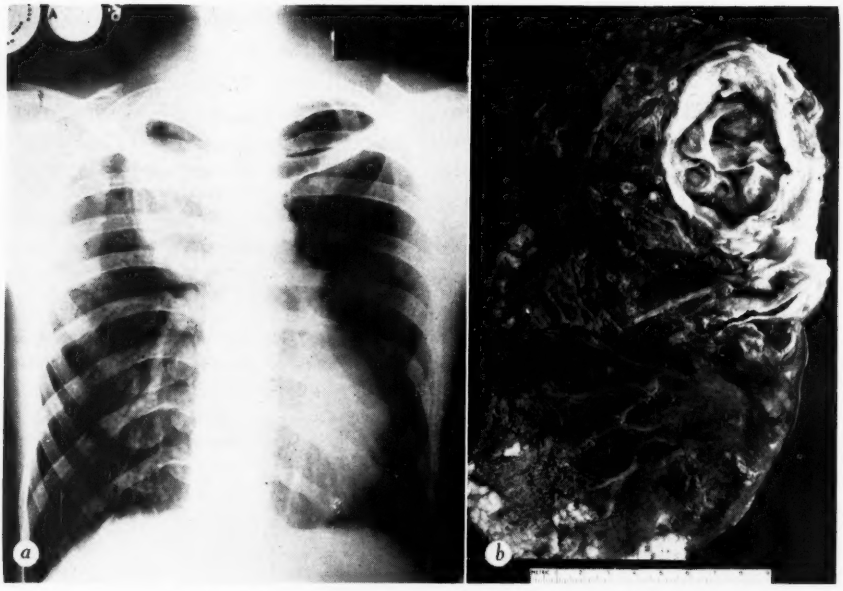

Fig. 3.—Case 2. *a*, thorax. *b*, gross specimen showing cyst.

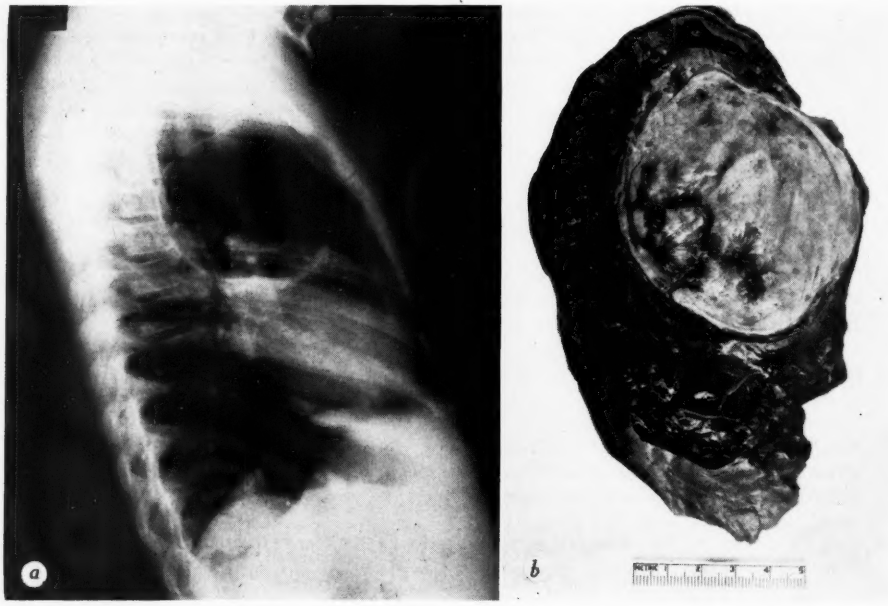

Fig. 4.—Case 3. *a*, lateral roentgenogram of thorax. *b*, gross specimen of cyst. Lining of cyst in this case is of indeterminate type.

CASE 4.—The patient was a woman 24 years of age. During the course of a routine general examination, roentgenographic examination showed a fairly well-circumscribed mass in the left upper portion of the thorax with partial atelectasis of the left upper lobe (Fig. 5*a*). Left upper lobectomy was performed. On examination of the gross specimen (Fig. 5*b*), the lesion was found to be a bronchiogenic cyst. This cyst, like most of the others, was trabeculated.

CASE 5.—The patient was a man 28 years of age. During the course of an Army examination a year previously, a diagnosis of spontaneous pneumothorax had been made. The patient was enjoying excellent health but was discharged from the service. Periodic roentgenograms of the thorax had been made, which seemed to indicate an increase in size of the pneumothorax. At the time of our examination, the roentgenogram showed a large, multilocular cyst in the apex of the left lung. At operation a large, thin-walled cyst was found filling the upper third of the pleural space and attached to the apex of the left upper lobe by a narrow pedicle. The cyst was removed. On microscopic examination the wall of the cyst was observed to be made up of fibrous connective tissue and lined by a flat, nonciliated type of cell.

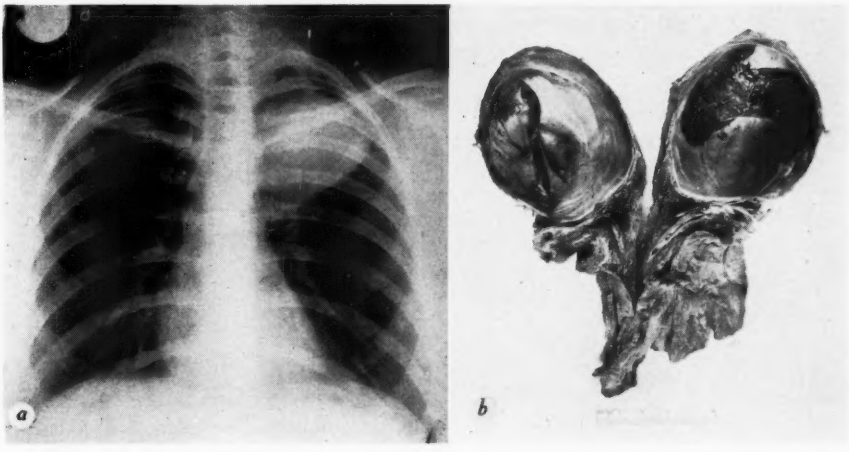

Fig. 5.—Case 4. *a*, thorax. *b*, gross specimen of cyst, which involved the left upper lobe.

Although in all of the cases of cystic bronchiectasis multiple cysts were present, in the other groups solitary cysts were the most frequent. In thirty-two of the thirty-six remaining cases the cysts were solitary, and in four, multiple. In the cases of pulmonary cyst of the multiple type, as might be anticipated, approximately the same pulmonary complications occurred as in the cases in which the cysts were solitary. This is illustrated in Case 6.

CASE 6.—The patient was a man 34 years of age. He stated that six months before coming under our observation, while attending a moving picture show, he had been suddenly seized with a severe pain in the substernal and epigastric region, associated with extreme dyspnea. He had been taken to the hospital, where a large amount of bloody fluid was aspirated from the left side of the thorax with prompt relief of the pain, although the dyspnea continued to a minor degree. Three months later a sharp pain again developed in the left costovertebral border. The pain required codeine for relief. A month later the patient began to cough up blood clots, which he continued to do up to the time of admission to the Mayo Clinic.

Roentgenograms of the thorax revealed two large circumscribed shadows involving nearly the whole left portion of the thorax. On surgical exploration the tumor masses were found to be two huge, rounded, globular cysts of approximately equal size, which practically filled the entire left portion of the thorax (Fig. 6). The lining of the cysts was perfectly smooth. On microscopic examination, tissue removed from the cyst wall was found to consist of fibrous hemorrhagic tissue covered with flat cells of an indeterminate type.

It has been mentioned that pulmonary suppurative disease may be an accompaniment of pulmonary cysts, and that such a suppurative process may be primarily responsible for the patient's symptoms. This is illustrated in Case 7.

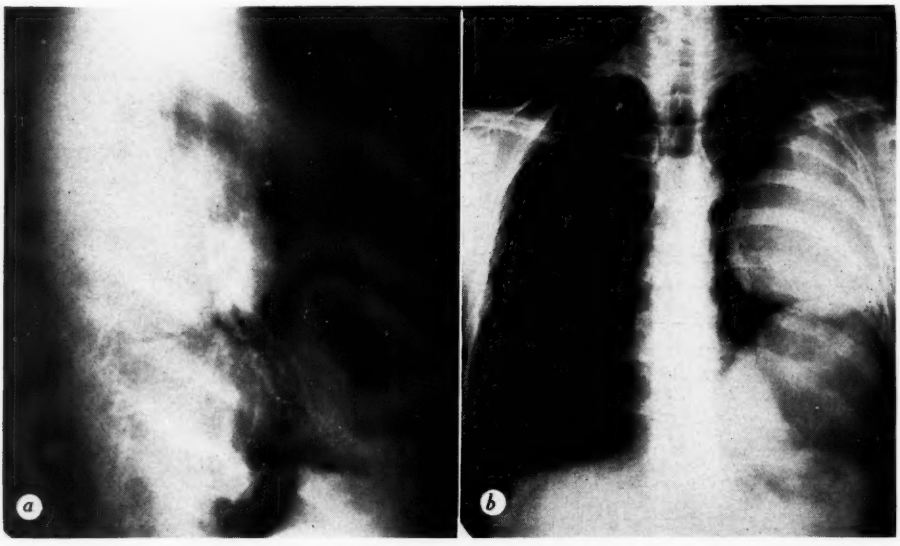

Fig. 6.—Case 6. *a* and *b*, roentgenograms of thorax, showing two large pulmonary cysts.

CASE 7.—The patient was a man, aged 56 years. He stated that in 1930, while he was undergoing a general examination, a roentgenogram of the thorax had been reported as showing a tumor which displaced the esophagus to one side. Because of lack of symptoms, nothing further was done at the time. Two years prior to admission to the Mayo Clinic, on roentgenographic re-examination, the tumor was again reported to be present in the thorax. In December, 1944, while eating some peanuts, he had a paroxysm of severe coughing which lasted several days and he was suspected of having aspirated a peanut. Three months later, he coughed out a few red blood clots, and three days thereafter he had severe hemoptysis which lasted for two days. He was hospitalized and penicillin was administered.

The patient was admitted to the Mayo Clinic a week later with a diagnosis of carcinoma of the lung. Roentgenologic examination revealed partial atelectasis of the right lower lobe. Bronchoscopy and bronchograms failed to show the presence of an intrabronchial tumor. Right lower lobectomy was performed and he was found to have a bronchiogenic cyst and extensive bronchiectasis with multiple small abscesses in the right lower lobe. No communication between the cyst and the bronchus could be demonstrated, and the cyst was not infected. It was our opinion in this case that the symptoms were secondary to the bronchiectasis and abscesses present in the right lower lobe rather than to the cyst. These secondary changes in the lung were very likely due to pressure of the

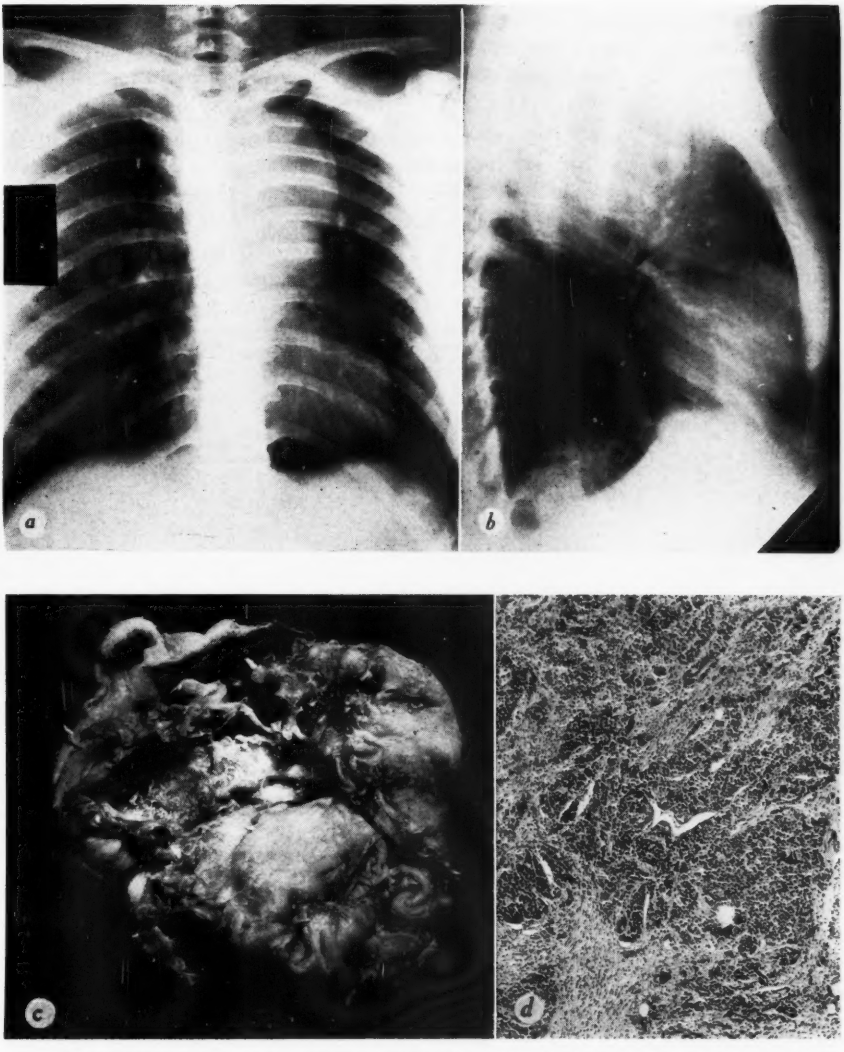

Fig. 7.—Case 8. *a* and *b*, anteroposterior and lateral roentgenograms of thorax, case of bronchiogenic cyst with carcinoma in wall of cyst; *c*, gross specimen of bronchiogenic cyst containing carcinoma; *d*, carcinoma found in wall of bronchiogenic cyst (×55).

distended cyst on the bronchus supplying the infected lung. As a result of interference with drainage of the bronchus distal to the obstruction, infection took place.

Bronchiogenic cysts are lined by a type of mucosa that might lend itself to the development of carcinoma. Womack and Graham[12] have reported epithelial hyperplasia and metaplasia in bronchial-lined cysts. It is surprising, however, that the occurrence of carcinoma in a bronchiogenic cyst has not been reported. It is well realized that great difficulty may be experienced in distinguishing between a carcinoma that has undergone cavitation and a bronchiogenic cyst in which a carcinoma has developed secondarily. The association of independent carcinoma of the lung and bronchiogenic cyst in the same lung has been reported. In the present study two cases were encountered which, from the duration of symptoms, the findings at the time of operation, and microscopic examination of the tissue, would indicate that carcinoma may develop secondarily in a pulmonary cyst. Cases 8 and 9 are two examples.

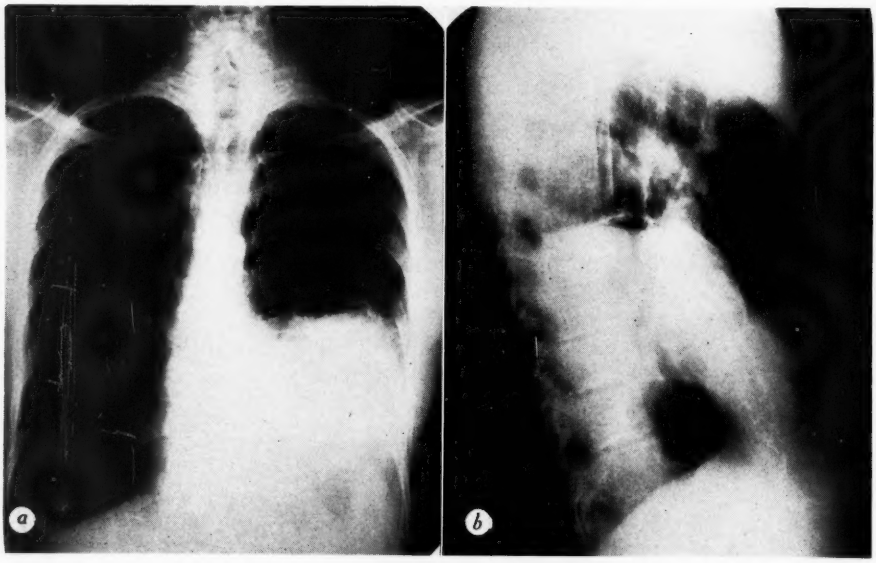

Fig. 8.—Case 9. *a* and *b*, anteroposterior and lateral roentgenograms of thorax.

CASE 8.—The patient was a woman 22 years of age. She had been well until two years previous to admission when, following birth of a child, she first noticed dyspnea. This gradually increased in severity. She was unable to lie flat in bed, and required two pillows to sleep. She had no cough and was referred to the Mayo Clinic as having substernal goiter.

Roentgenologic examination of the thorax showed a widening of the upper part of the mediastinum suggestive of aneurysm (Fig. 7*a* and *b*). Roentgenoscopic examination was reported as showing a nonexpansile tumor in the upper part of the mediastinum. At operation a tumor was removed from the left part of the thorax. The tumor had a thick, fibrous capsule containing 1,000 c.c. of fluid. On microscopic examination it was reported as a bronchiogenic cyst with an adenocarcinoma of grade 3 (Broders' method) arising in the wall (Fig. 7*c* and *d*).

CASE 9.—The patient, a man 36 years of age, had had pulmonary difficulty since childhood. He stated that when he was a boy a diagnosis of pulmonary tuberculosis had been made and he had spent nine months in a sanatorium. Three years before coming under our observation there developed a pain in the left side of the thorax associated with what was called an effusion. A tube was inserted into the thorax, through which fluid drained for ten days, when the tube was removed. Since then, his thorax had been aspirated every one or two weeks and amber-colored fluid had been removed. If the fluid was allowed to remain in the thorax longer than two weeks without aspiration, a low-grade fever would develop and he would feel achy. In spite of his long illness, he had lost but 15 lbs. (6.8 kg.).

At the time of our examination, the roentgenogram was reported as showing a large cyst involving the left side of the thorax, with calcium in the wall of the cyst (Fig. 8*a* and *b*). Surgical exploration was performed, and a large, calcified, cystic tumor was found in the left side of the thorax, fixed to the anterior thoracic wall. The cyst contained 300 c.c. of bloody fluid. The wall of the cyst was lined for approximately three-fourths of its surface by a thick layer of calcium. In a region of the cyst wall opposite the pericardium there was a mass of soft tissue. Tissue removed from this region was reported on microscopic examination to be a squamous cell carcinoma, grade 4 (Fig. 8*c*).

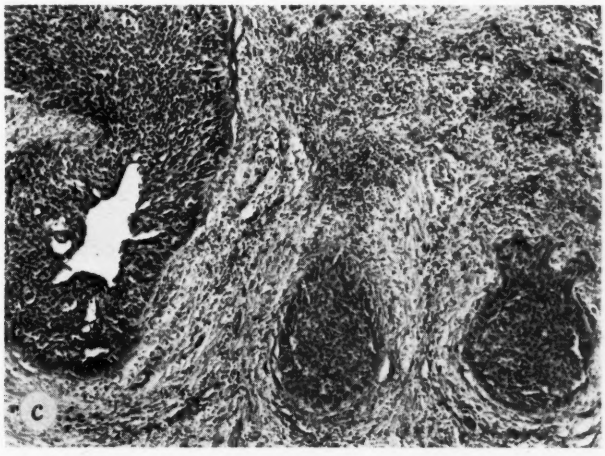

Fig. 8.—*c*, section removed from carcinoma arising in wall of cyst (×65).

There may be some question as to the justification of including cystic bronchiectasis in the same category with pulmonary cyst. The cases of cystic bronchiectasis, however, have been included for study as they throw some light on the probable etiologic factors involved in the development of bronchiogenic cysts and illustrate the difficulty that may be experienced in differential diagnosis. The following case is especially instructive in this respect.

CASE 10.—The patient, a woman 22 years of age, gave a history of a productive cough from which she had suffered all her life. The condition had been diagnosed as one of bronchiectasis, and she had undergone numerous bronchoscopic and bronchographic studies. She raised approximately a half cupful of purulent sputum daily and had suffered from several frank hemorrhages.

At our examination, which included bronchographic studies, she was found to have bronchiectasis involving the right lower lobe, left lower lobe, and left lingula. In view of

the patient's difficulty, bilateral lobectomy and left lingulectomy seemed advisable. Right lower lobectomy was performed and she made an uneventful recovery. She returned five months later to have the left lower lobe and lingula removed. Before proceeding with operation the bronchograms were repeated and revealed extensive cystic bronchiectasis involving the right middle lobe. Bronchoscopy, as well as the bronchographic studies, failed to reveal any evidence of obstruction in the bronchus leading to the middle lobe. It is very likely, however, that following the right lower lobectomy some distortion of the right middle lobe bronchus took place, leading to a ball-valve action and production of dilatation of the bronchi and development of cystic bronchiectasis.

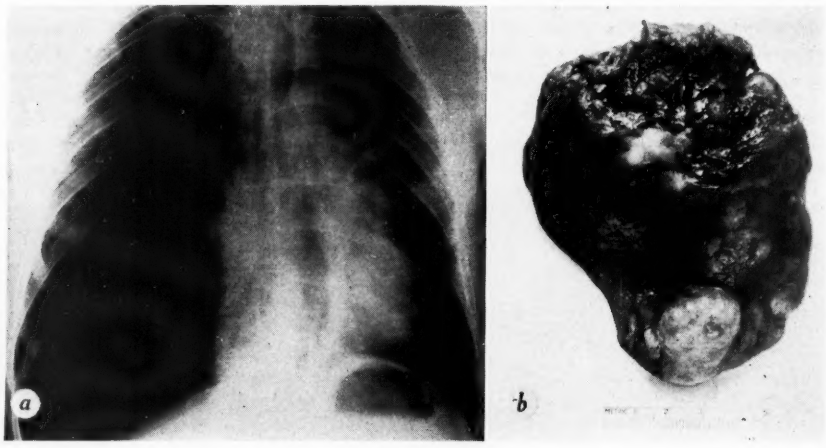

Fig. 9.—Case 11. *a*, thorax; *b*, gross specimen of cyst.

CASE 11.—The patient was a man 41 years of age. Six months prior to admission severe dyspnea with associated cough had suddenly developed. The dyspnea continued up to the time of admission to the Mayo Clinic.

On roentgenologic examination of the thorax the patient was found to have tension pneumothorax on the right side with mediastinal herniation and shift of the heart and mediastinum to the left (Fig. 9*a*). Continuous suction was started and there was some re-expansion of the lung, but on discontinuation of suction the tension pneumothorax rapidly recurred. Exploratory thoracotomy was carried out and the patient was found to have multiple cysts in the right middle lobe with a large opening communicating between one of the cysts and the pleural space. Right middle lobectomy was performed with success. The gross specimen is shown in Fig. 9*b*.

DIAGNOSIS

The diagnosis of pulmonary cysts is at times a relatively easy matter but more often taxes diagnostic acumen to the utmost. Errors in diagnosis are characteristic of the condition. A careful clinical history may often give the first inkling of the existence of a cyst. In the absence of pulmonary symptoms the diagnosis is fortuitous. Physical examination of the chest, although always indicated, seldom adds materially to the diagnosis. Clubbing of the fingers is usually present in the cases of cystic bronchiectasis but is a less frequent accompaniment of pulmonary cyst. By far the most valuable diagnostic

aid in the recognition of pulmonary cyst is roentgenologic examination of the thorax. Kirklin[13] has clearly indicated that the facility with which pulmonary cysts can be diagnosed roentgenographically varies according to their contents, size, situation, and the presence or absence of complications. Although the air-containing cysts usually can be readily identified, those completely filled with fluid offer an extremely difficult diagnostic problem. However, the information that is contributed by roentgenography, when correlated with clinical facts, will often aid greatly in arriving at an accurate interpretation. Roentgenologic examination of the esophagus may also occasionally contribute information in this respect.

Bronchoscopy, in our experience, has seldom been of positive value in the diagnosis of pulmonary cysts. (It may be at times of aid in excluding other pulmonary lesions which might present a picture that resembles pulmonary cysts.) We have also found bronchography to be of very little value in the diagnosis of pulmonary cysts other than cystic bronchiectasis. This is due to the fact that it is almost impossible to get oil into the cyst by this method. The direct injection of oil into the pleural space or the cyst itself, as suggested by Singer,[14] will give much more valuable information in the diagnosis of pulmonary cyst than will bronchography. Singer has found the measurement of air pressure within the cyst and pleural space of value in the diagnosis of pulmonary cyst. When there is a question of distinguishing between a vascular tumor and a pulmonary cyst, angiocardiography, as described by Greenfield, Steinberg, and Touroff,[15] may be of value.

With the great improvement that has taken place in the field of thoracic surgery in recent years, we feel that, if there is doubt as to diagnosis, exploratory thoracotomy is to be highly recommended.

DIFFERENTIAL DIAGNOSIS

Pulmonary cysts frequently offer an extremely difficult problem in differential diagnosis. Among the more common conditions from which they must be distinguished are pulmonary tuberculosis, carcinoma, neurofibroma, pulmonary abscess, vascular tumor, empyema, pneumothorax, substernal thyroid, and mediastinal tumors. In the present study, the condition with which they were most frequently confused was tuberculosis. In six of the cases the patients had been treated for tuberculosis. Three of these had undergone periods of pneumothorax. It is rather surprising that the second most frequent source of error in differential diagnosis was in distinguishing pulmonary cyst from substernal goiter. Three of the patients had been operated on erroneously because of this error.

Maier and Haight[4] very forcibly called attention to the ease with which pulmonary cysts may be mistakenly treated as empyema, and pointed out the reasons why drainage will not result in cure. Our experience has been in agreement with theirs. Case 12 is an example of this type.

CASE 12.—The patient was a woman 18 years of age. Three years before she came under our observation, right-sided pleural pain suddenly developed, and almost immediately

thereafter there developed right-sided empyema which was thought to be secondary to unrecognized pneumonia. She stated that diagnostic aspiration of the thorax a week after onset of her difficulty had revealed pus, and drainage had been established through a stab wound. Eight weeks later, resection of a rib was performed. Drainage was maintained for a period of a month, and the incision then was allowed to close. It remained closed for a year but the patient continued to expectorate foul material. An incision was again made and permitted to drain for three weeks, following which the same sequence as before occurred. A year prior to admission to the Mayo Clinic a tube was inserted into the so-called empyema pocket and had been maintained since. If the tube drained well the cough and expectoration disappeared.

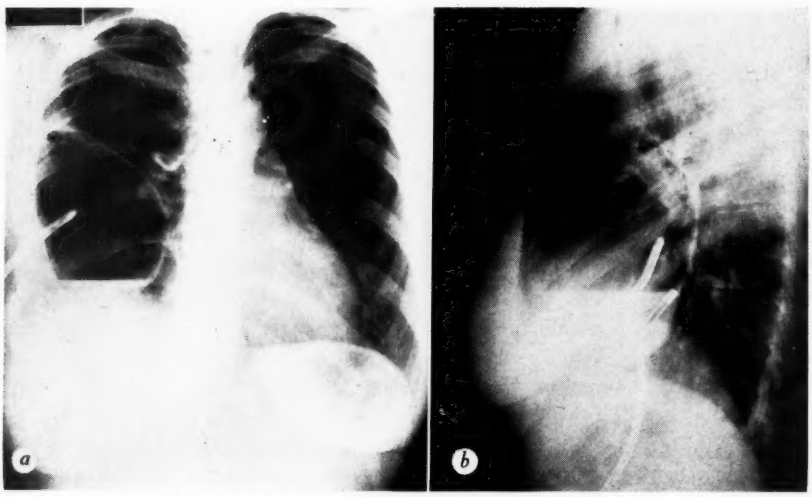

Fig. 10.—Case 12. *a* and *b*, anteroposterior and lateral roentgenograms of thorax.

At the time of our examination, roentgenographic examination of the thorax (Fig. 10) revealed a cavity in the right side of the thorax with a fluid level in the lower portion and with a drainage tube in place. In view of the history and roentgenographic findings, a diagnosis of infected pulmonary cyst was made and operation was advised. At the first operation, open drainage of the cyst was established, but this, coinciding with the experience of Maier and Haight, failed to be followed by successful results. At a subsequent operation the cyst was dissected out with complete relief of the patient's symptoms. On microscopic examination the cyst was found to be a bronchiogenic cyst with multiple bronchial communications.

A case of bronchiogenic cyst in which the patient had been treated for tuberculosis, pneumothorax, and allergy is presented in Case 13. This case is also of interest as roentgenograms were available which demonstrated the various stages in the development of the cyst.

CASE 13.—The patient was a woman 40 years of age. A chronic cough had first developed between the ages of 12 and 16 years. She would often raise rather large quantities of thick yellow sputum but never any blood. When she was 17 years of age the condition was thought to be tuberculosis. One test of sputum positive for tuberculosis was reported, but this finding was never confirmed subsequently. She was kept in bed on and off because of her difficulty. At 20 years of age, she began to have intermittent bouts of fever, cough, and

expectoration of six to eight fluid ounces (180 to 240 c.c.) of purulent material, after which she would feel better. She was treated intermittently for tuberculosis, allergy, and various other conditions.

She first came under observation at the Mayo Clinic in 1935, at which time the roentgenogram of the thorax was reported as showing an old tuberculous lesion of the second interspace and both apexes. An obstruction of the left upper lobe was found on bronchographic studies. The cause of the patient's difficulty was not established. She continued to have the same pulmonary symptoms and returned to the clinic in 1945. At this time the roentgenograms revealed a lobulated mass extending into the anterior parenchyma of the left lung from the left hilus. The long story of pulmonary difficulty and the roentgenologic findings suggested that the lesion was probably due to a pulmonary cyst, and operation was advised. On surgical exploration, the upper lobe was found to be almost completely atelectatic and to contain one good-sized bronchiogenic cyst.

The following case is of interest because of the short history and the fact that the lesion had been diagnosed as a diaphragmatic hernia.

CASE 14.—The patient was a man, 47 years of age, who was sent to the Mayo Clinic with a diagnosis of diaphragmatic hernia. He had a two-week history of pain in the left side of the thorax, cough, and expectoration. Our roentgenograms showed a large cyst in the left side of the thorax. At operation a large bronchiogenic cyst was removed.

TREATMENT

The treatment of pulmonary cysts of the type described in this paper is entirely surgical. Theoretically, it might be assumed that a pulmonary cyst, either with or without a bronchial communication and not giving rise to symptoms, might safely be allowed to remain undisturbed. Unfortunately, it is in cases of this type that the differential diagnosis is especially difficult or impossible, and exploration becomes necessary to avoid the possibility of allowing a condition of more serious nature to remain. Exploratory thoracotomy is especially advisable since the thoracic surgeons have reduced the risk of this operation to such a low level. An added reason for the prompt extirpation of pulmonary cysts becomes self-evident in view of the possibility of development of carcinoma in such a cyst, as exemplified in two of our thirty-six cases of pulmonary cyst (the cases of cystic bronchiectasis not being included here).

As to the type of operative procedure to be employed in any given case of pulmonary cyst, this necessarily must depend on the location, attachment, pulmonary involvement and secondary complications present. The essential point, however, is to remove the cyst in its entirety.

CONCLUSIONS

1. Pulmonary cysts are of special interest because of the variability in the clinical symptoms that they may produce and the difficulty that may be experienced in their differential diagnosis.

2. They may be divided into two main types, those arising from the bronchial mucosa and those that are alveolar in origin. There may be various gradations between these two types.

3. The causation of pulmonary cysts is not definitely established. While many are congenital, clinical evidence would seem to indicate that many are

acquired. A study of cystic bronchiectasis illustrates the rapidity with which cystic dilatation of the bronchi can take place.

4. Pulmonary cysts with a bronchial communication are more likely to give rise to clinical symptoms than those in which such a communication does not exist, although the latter can give rise to clinical symptoms primarily due to pressure on neighboring bronchi and subsequent bronchial infection.

5. Cough, expectoration, hemoptysis, thoracic pain, and attacks of fever are the chief symptoms found associated with pulmonary cysts.

6. Two cases are presented that would indicate that carcinoma may develop within a pulmonary cyst.

7. The treatment of pulmonary cyst is best accomplished by its surgical removal.

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DISCUSSION ON "SURGICAL THORACIC TUMORS IN NAVY PERSONNEL" BY DR. W. L. WATSON, AND DR. HENRY D. DIAMOND,* AND "PULMONARY CYSTS" BY DR. HERMAN J. MOERSCH AND O. THERON CLAGETT†

DR. EVARTS A. GRAHAM, St. Louis, Mo.—I think it is a good thing that Dr. Moersch has brought to our attention the question of pulmonary cysts. These not only are much more common than we used to think, but they have a very important significance that is too often overlooked or perhaps not fully realized.

*See page 1, February, 1947, issue for article by Watson and Diamond.
†See page 179 for article by Moersch and Clagett.

Dr. Moersch mentioned one of his patients who is 75 years old. That is a very old age for a patient to have a pulmonary cyst. It is seldom that one finds patients beyond middle age with pulmonary cysts. I think this means that patients who have congenital cystic disease of the lung seldom reach middle age. Therefore, it is a matter of great importance that we diagnose these conditions early and that we subject the patient to adequate treatment.

Why don't they live to middle age or beyond? In the first place, there is the element of infection, which carries off a good many of them. Dr. Womack and I, however, for a number of years have been convinced that there is a great tendency for cystic disease of the lung to develop into carcinoma, and carcinoma probably carries away a good many of the patients with cysts.

There is nothing strange in that conception. It is well known among pathologists that congenital abnormalities are particularly likely to take on malignant changes. Therefore, such a conception would fit in very well with the idea that congenital cystic disease of the lung may also be associated with high incidence of malignancy.

Dr. Moersch was kind enough to refer to our work, which was published in 1941, in the *Army Journal of Pathology*, in which we called attention to this fact and illustrated the article with several photomicrographs which showed, in some cases, areas which, I think, one would be justified in calling carcinoma.

Dr. Moersch's cases again illustrate that very important point.

I have three slides that I should like to put on the screen for a moment, which I think illustrate a comparatively late stage of carcinoma more than merely the microscopic stage in association with congenital cystic disease.

Some may protest the diagnosis in one or two of these cases and say that what I am showing is not congenital cysts but merely congenital bronchiectasis. I will say, in reply to that, that the microscopic examination of these cysts (slide) showed the cavities to be lined by epithelium. There was no thickening of the wall, nothing at all like what one sees in bronchiectasis. This was a massive carcinoma. Whether it arose in this cyst or not, is, of course, impossible to tell.

(Slide.) Here is another which shows some bronchiectasis. In this lobe are thickened bronchi, but there are also areas in which the lining of the cyst is thin, and microscopically it shows nothing but unaltered epithelium. Yet there was an obvious carcinoma here.

These areas of bronchiectasis probably are a result of obstruction of the bronchus from the tumor, with later infection causing thickening.

(Slide.) Here again is a case which some may question as to whether or not the cysts are really congenital in origin, or merely dilatations caused by bronchial obstruction, but I am showing them to you because again careful microscopic examination of some of these cysts showed merely a thin wall with essentially normal epithelium and one not altered by infection as one would expect in the case of bronchiectasis.

In summary then, it seems to me that congenital cystic disease of the lung should be always regarded as a very serious disease, and one which is not likely to permit the patient to reach middle age or beyond. It, therefore, requires attention, and the treatment of the condition should not be postponed indefinitely.

DR. ALTON OCHSNER, New Orleans, La.—It is astounding how large these cysts can become in children and produce relatively few symptoms. I would like to show slides of two of a series of twelve pulmonary cysts which we have had.

Both the patients were younger than 2 years of age. One was an infant admitted into the clinic because of a congenital anomaly of the penis. A routine x-ray was taken of the chest, and much to the astonishment of everyone, the entire right hand of the thorax was completely filled by cyst. The child appeared perfectly well, and presumably was well.

Upon interrogation of the family, we learned that when the child cried a great deal, a slight cyanosis was noted, which the mother and father thought was simply because the child cried as badly as he did.

The child was operated upon, and the cyst was removed.

The other patient was 2 years of age. At the age of 5 months the child developed an upper respiratory tract infection of the cavity, which was drawn, and thought to be an empyema. The true nature of the condition was not considered until later.

(Slide.) This is the right-hand thorax. The mediastinum was shoved over here, and at operation it was found that the cyst arose from the inferior portion of the upper lobe, and that the remaining portion of the lung was pressed down in the inferior portion on that side.

There was a question whether we should not have left a pneumothorax in this patient because subsequently, in spite of the fact that no fluid was given, this child developed a rather marked edema of the lung. Whether that was due to the fact that there was a rapid expansion of the lung, I do not know.

(Slides were shown of both cysts which were removed.)

Both of these cysts look somewhat smaller than they actually were, because they were opened in removal, and it was necessary to fill them.

DR. H. BRODIE STEPHENS, San Francisco, Calif.—Did you find any bronchial communication?

DR. OCHSNER.—The first one had a definite communication. We aspirated the cyst and it filled up within a very short time.

DR. WILLIAM E. ADAMS, Chicago, Ill.—(Slide.) From a study of twenty-one personal cases of this type of lesion, we have been impressed with the difficulty in differential diagnosis and the fact that over 75 per cent of the cases have been treated for a matter of months, or even years, for other conditions before the lesion was diagnosed.

We reviewed twenty-six cases reported in the literature for comparison with our own, and about the same experience was had by the authors reporting.

Of the twenty-one cases, fifteen had been diagnosed as bronchiectasis, seven as lung abscess, four as empyema, and so on through pneumothorax, pneumonitis, diaphragmatic hernia, chronic bronchitis; the other reported cases, as you see, had about the same frequency as in our own series.

In eleven of the cases reported, there had been no diagnosis prior to exploration.

(Slide.) I will illustrate a few of these cases.

A woman, 25 years old, with an x-ray following iodized oil injection, shows the characteristic appearance of bilateral bronchiectasis. It was only after the surgical specimen was opened and pathological section was made, that the true nature of the lesion was discovered. This is a postoperative x-ray after the first operation.

(Slide.) Here we see a section through the entire middle lobe, showing it composed entirely of large, irregular, cystic spaces with no normal lung tissue demonstrable.

In four other cases that had been diagnosed as bronchiectasis, all were located in the right middle lobe. In this differentiation it is not usually so important because the treatment would be the same for bronchiectasis as for cystic disease. However, in some cases the lesion might appear to be so extensive that operation would seem ill advised.

(Slide.) Here is a boy of 12 who had had a drain in a supposed lung abscess of the left lower lobe for twelve years. It had been allowed to close, redrained and closed on four different occasions, so that twelve years prior to admission he had carried this drainage tube.

Unfortunately, this slide does not show well the fluid level just below the dome of the diaphragm.

(Slide.) This shows again a large cyst with much fibrosis and abnormal development of tissue and no normally developed lung in the section.

(Slide.) This particular case, a girl of 19, who had had a diagnosis of upper respiratory infection, had had colds and coughed without much production. Even on fluoroscopy, these fluid levels were not demonstrable. She was followed for one year, and given various kinds of cough medicine. Finally the cyst produced fluid, the fluid level was seen, and the true nature of lesion was suspected.

(Slide.) A specimen, showing the locculated cyst, and, in this case, a great deal of normally developed lung tissue surrounding. Those cases having a thin-walled cyst with much normally developed lung tissue surrounding, may not be demonstrable until a fluid level is produced.

(Slide.) This last case was a boy, 10 years old, who had had an insidious onset with a productive cough, and loss in weight, and came into the hospital with the x-ray seen on the left. Aspiration was made without obtaining any information. Bronchoscopy showed pus coming from the left side. Exploration of the chest was advised. He had to be prepared for this because he was markedly anemic.

At exploration it was found that the lower lobe was completely infiltrated; the upper lobe was atelectatic. The lower lobe only was removed.

The picture shows that the upper lobe had not been reaerated, but some time later it became inflated, and this is a picture several months following operation.

(Slide.) Here we see the specimen. There are many cystic spaces with no normally developed lung tissue.

(Slide.) A microscopic section through the lower lobe revealed many cystic spaces, all of the tissue being abnormally developed lung.

So we frequently have a great deal of difficulty in being able to diagnose the condition definitely without exploration.

DR. ALFRED GOLDMAN, Los Angeles.—We have had a fair experience with cysts, and I would like to show one that has an onset of symptoms different from that listed in the paper of Dr. Moersch.

The onset of this patient's symptoms was diagnosed as spontaneous pneumothorax. She was 18 years of age at the time of onset of symptoms. This shows the air-contained area in the right pleural cavity, which was diagnosed as pneumothorax and was continued therapeutically for several months by the doctor who first saw it. Actually, the supposed spontaneous pneumothorax was air under positive pressure in the cyst.

(Slide.) This is a picture of the cyst at operation, with a stalk that went into the area of the mediastinum at the bifurcation of the trachea.

(Slide.) This is a gross specimen of the cyst, showing the cyst and the ragged outside, where the numerous adhesions were attached, and the rudimentary bronchus or stalk.

(Slide.) This shows the microscopic appearance of one of the nodules in the wall of this cyst. Here is a rudimentary esophagus and rudimentary spleen.

(Slide.) This shows the character of the main lining of the cyst, the columnar epithelium that appeared to be ciliated.

This case was registered at the Tumor Registry, and Dr. Ash called it a teratomatous cyst in an abnormally developed lobe.

(Slide.) This is a slide postoperatively, showing a complete expansion of the remaining lobes which, by the way, showed no carbon deposits on the surface.

DR. LEON J. LEAHY, Buffalo.—The question arises in my mind as to the proper time to treat these cysts surgically.

I thought Dr. Gross's recent paper, describing a case of a child 23 days old upon whom he performed a total pneumectomy with an excellent result, was very outstanding.

We recently had a child about whom we were very concerned, but eventually had a satisfactory result.

(Slide.) This is a 2-year-old child, admitted to the Children's Hospital, who went through the gamut of differential diagnosis of lung abscess empyema, and so forth. One of the enthusiastic house men aspirated this cyst, which you can see in the lower lobe, obtained 85 c.c. of Type 32 pneumococcus pus, which was thin, whereupon the child, who had been ill with a temperature of 104° F. and pain in the chest, recovered and went home.

We saw him, after the episode of tapping, believed he had a cyst, and should return for surgery.

(Slide.) This case was complicated by pectum excavatum, which we thought in some way might contribute to the heart on the right side, and did not think it was entirely due to tension from the cyst.

The child was taken home, and followed by a competent pediatrician, who felt he was not developing normally, was markedly underweight, apathetic, sat around instead of playing, and was dyspneic on exertion. He was brought back to the hospital.

(Slide.) This time the cyst has disappeared from the lower lobe, as far as x-ray is concerned, but the upper lobe is markedly distended, mediastinum displaced, with the heart in the right chest. We diagnosed cystic disease of the lung and performed total pneumectomy.

The child is active now, playing and gaining weight. He is an entirely different child.

(Slide.) This is an x-ray specimen of the lung. You see the large involvement of the upper lobe. The lower lobe is fibrotic and the cyst cannot be shown here, but in the examination of the specimen it was found converted into merely a narrow slit.

(Slide.) This shows merely high columnar epithelium lining.

(Slide.) This film was taken Monday of this week. The heart has come back somewhat and the mediastinum is no longer displaced. A further question is whether or not the displacement of the heart was due to the sternum.

JEROME R. HEAD, Chicago, Ill.—Wherever congenital epithelial cysts occur in the body, the type of lining epithelium is usually ciliated. This fact casts doubt upon the conception that such cysts in the mediastinum and lung are necessarily of bronchial origin. There are other facts which strongly suggest that they are. One is that cartilage is usually found in their walls, and another is that examples are encountered which suggest that the isolated cysts of the mediastinum, the solitary cysts embedded in the lung, and congenital cystic accessory lobes are manifestations of the same error in development. All of these are located in the posterior thorax, and all are fed by an artery arising from the aorta and drained by a vein running to the vena cava. In one instance I have encountered congenital cystic accessory lobe which hung by a relatively small pedicle from the mediastinal edge of the base of the left lower lobe. Its bronchial system was continuous with that of the normal lower lobe, and there were some blood vessels in the pedicle. But the main blood supply was an artery ¼ inch in diameter arising from the thoracic aorta. That the cysts which are purely in the mediastinum and those which are partially embedded in the lung have this same blood supply suggests very strongly that they are all different stages in the same developmental error.

I would like to present one other observation regarding these tumors. They are practically the only intrathoracic growths which are molded by their surroundings. Most others grow firmly and strongly from a center to form the regularly curved outlines of a sphere. These, on the other hand, often have one side flattened by contact with the chest wall or an interlobar septum. This is of diagnostic importance.

DR. HARRY C. BALLON, Montreal.—I hesitate to come before this society to present clinical experiences without histologic proof. I would like to draw to the attention of this audience, six experiences with infected cysts of the lung occurring in infants between the ages of 3 weeks and 3 months. My first such patient was observed in 1934.

In every instance the cyst contained air and pus under tension. Pneumococcus type III was cultured from the pus in two instances. These cysts were concluded to be bronchial in origin either because when injected with lipiodol the oil failed to enter the parenchyma, or because of the lack of parenchymal reaction, and/or because of rapid collapse of the cyst wall following aspiration. All were treated by aspiration. None of

these patients developed complications, recurrences or secondary bronchiectasis. In two instances pus was demonstrated in the gastric contents which obviously implied a bronchial communication. It is suggested that most lung cysts are in reality bronchial cysts and that some lung cysts observed in adults are either congenital or develop during infancy. The possibility that infected balloon-tension cysts in infants may be subsequent to suppurative bronchopneumonia cannot be denied. So-called mediastinal cysts which usually contain clear fluid will not respond as readily to aspiration. They are frequently reduplication cysts in the same sense as intestinal reduplications.

In many instances in the adult the histologic appearance of a so-called primary tells one but little about the evolution of the cyst.

DR. E. F. BUTLER, Elmira, N. Y.—I would like to corroborate what Dr. Head has said about the occurrence of anomalous vessels in these cases. I have encountered such anomalous arterial trunks in at least four, possibly five, operations for lesions which could be considered infected congenital cysts of the lung. One of these anomalous arteries apparently arose from a point below the diaphragm and perforated the diaphragm. The others all arose from the thoracic aorta, above the level of the diaphragm.

These vessels constitute an added hazard whenever lobectomy or pneumonectomy is undertaken for presumptive congenital lesion of the lung. In one instance, and I regret to say the last instance, fatal hemorrhage resulted from trauma to such a vessel.

TRANSTHORACIC REPAIR OF LARGE DIAPHRAGMATIC HERNIAS

An Experimental Study

Tague C. Chisholm, M.D.*
Boston, Mass.

NUMEROUS writers have reviewed the many aspects of the problems associated with diaphragmatic hernias. Their studies have covered the anatomy and embryology of the diaphragm, the classification and clinical diagnosis of diaphragmatic hernia, and the surgical treatment of the same. Large numbers of diaphragmatic hernias have now been repaired successfully. Surgical reconstructions have failed with recurrence where the defects have been very large, chiefly because the repair was accomplished with too great tension, which resulted in a breaking down of the suture line. In some instances the reconstruction was followed by death, where the intra-abdominal tension was too great following surgical repair, resulting in such impairment of vital processes as thrombosis of the portal vein and/or the vena cava.

In 1942, Rives and Baker[1] published an excellent account of the anatomy of the attachments of the diaphragm, and reported their experience in one human being where a large, recurrent, posterior, diaphragmatic hernia was successfully repaired by means of a sliding fibromuscular flap. From this report the writer became interested in following, in experimental animals, the suggestions of Rives and Baker to determine the fate of voluntary skeletal muscle employed to repair involuntary skeletal muscular defects in the diaphragm and to determine the general applicability of such a method of repair in diaphragmatic hernia surgery.

EXPERIMENTAL METHOD

In these experiments, eighteen mongrel dogs ranging from 14 to 22 kg. in weight were employed. Following the subcutaneous administration of 15 mg. of morphine sulfate and 0.6 mg. of atropine sulfate, anesthesia was induced with ethyl ether by the open drop method. Subsequently, a rubber tracheal catheter was introduced and ether was administered under intermittent positive pressure with the use of the Erlanger apparatus.

Dogs were then placed on the operating table with the right side down. An incision was made over the left tenth rib from the costochondral junction anteriorly to the angle of the rib posteriorly. After the skin and platysma were divided, the latissimus dorsi was freed and incised over the upper border of the tenth rib. The free edge was clasped with Allis clamps and reflected downward below the eleventh rib as a pedicle. The eleventh rib was removed

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subperiosteally from the costochondral junction to the posterior angle. The pleura was incised through the bed of the eleventh rib, and the left lung was collapsed.

Because of the respiratory action of the diaphragm, it was considered necessary at the start of the experiments to paralyze the phrenic nerve. In the first ten dogs, the left phrenic nerve was crushed about two inches above the diaphragm. Subsequently, two dogs had one per cent acid procaine injected into the nerve at about the same level. On the last six dogs the method for excising the left diaphragm was altered from the original plan and neither injections nor crushes of the phrenic nerve were carried out. In the first twelve dogs a longitudinal slit was made through the central tendon and an elipse of diaphragmatic tissue was removed from each side; in the last six dogs a large single piece was excised starting laterally close to the costal cage and working around posteriorly toward the esophagus and anteriorly toward the pericardium. A total of three quarters to nine tenths of the entire left diaphragm was removed in each animal, leaving an enormous defect. When the margins of the defect could be joined to one another only with considerable tension on the suture line, the excision was considered adequate (Fig. 1).

The experimentally produced, large, left diaphragmatic hernia was repaired by utilizing the pedicle of the caudal portion of the latissimus dorsi. In the first five dogs it was observed that the pedicle could be swung into the pleural cavity and used to close the defect with no tension except at point *B* (Fig. 2). Points *A* and *B*, at the base of the esophagus and at the margin of the thoracic wall, represent the longest distance to be transversed by the pedicle. In subsequent experimental animals this was avoided by first joining opposite edges of the diaphragmatic defect, starting at point *B*, with a few interrupted mattress sutures. The distance to be transversed by the pedicle was then sufficiently lessened to permit the remaining defect to be closed with minimal tension on the suture line. Careful scrutiny of Figs. 2 and 3 indicates the exact directions in which the sutures were passed to permit the operator to draw the pedicle down to the remaining rim of the diaphragm without tension; note that the knots are tied on the side away from the new sliding flap.

With the left lung reinflated to nearly normal volume, the chest wall was closed by suturing the cut edge of the cephalad portion of the latissimus dorsi to the tenth intercostal substance and both of these to the central portion of the caudal pedicle where it crossed the cut edge of the bed of the eleventh rib (Fig. 4). The attachments of the cephalad portion of the latissimus dorsi were thus restored, and shoulder girdle motions involving external rotation of the humerus were normal. The wound was then closed in layers with subcuticular stitches to the skin.

Four-pound test, fine black silk was employed throughout the operative procedures. All wounds healed per primam with one exception, in which the stomach was excessively distended from recently ingested food and continually interfered with the exposure. The stomach was opened and washed out. On the fourth postoperative day, fulminating empyema necessitated sacrifice of the animal.

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Fig. 1.

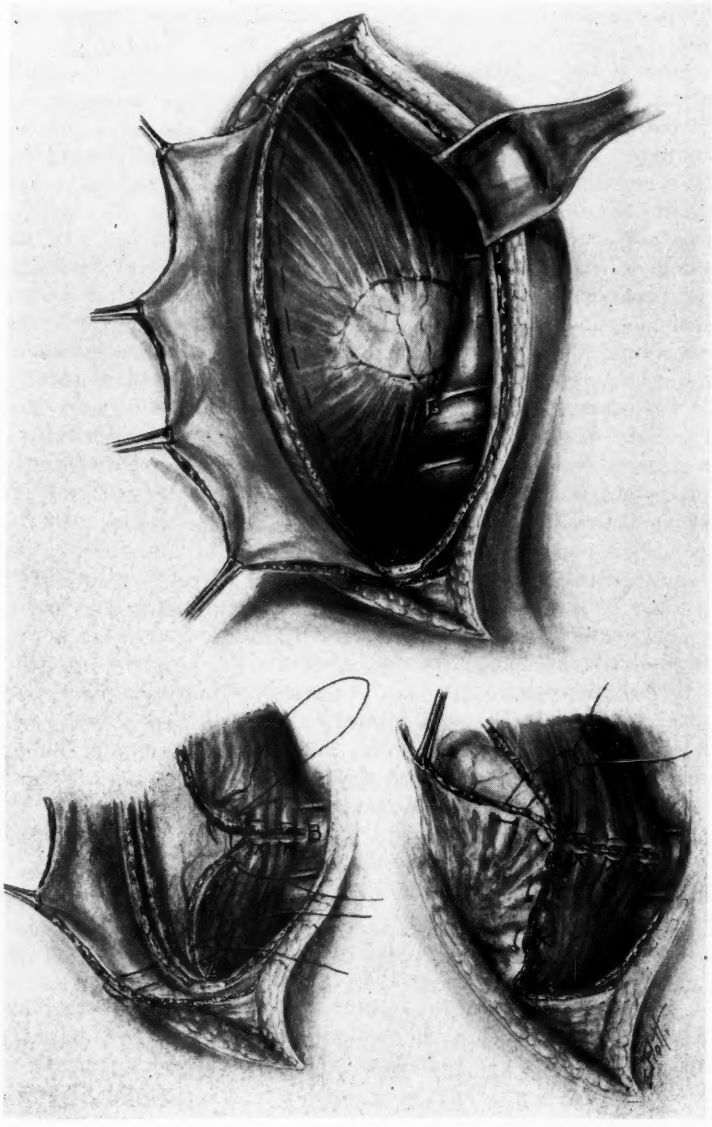

Fig. 2. Fig. 3.

Fig. 1.—Diagrammatic drawing of the left thoracic cage with dotted line indicating that portion of the diaphragm to be excised.

Figs. 2 and 3.—Diagrammatic drawings indicating the method of suturing the pedicle of the latissimus dorsi to the medial remnant of the diaphragm.

RESULTS

Follow-up studies on our dogs extended from three weeks to eleven months. There was practically no significant external deformity with only a slight concavity over the site of the rib resection (Fig. 5). Locomotion was unimpaired, and the cephalad portion of the latissimus dorsi maintained good tone without any atrophy. X-rays of the chest showed a flattened left diaphragm without hydrothorax or pneumothorax (Fig. 6). The heart was not displaced and the

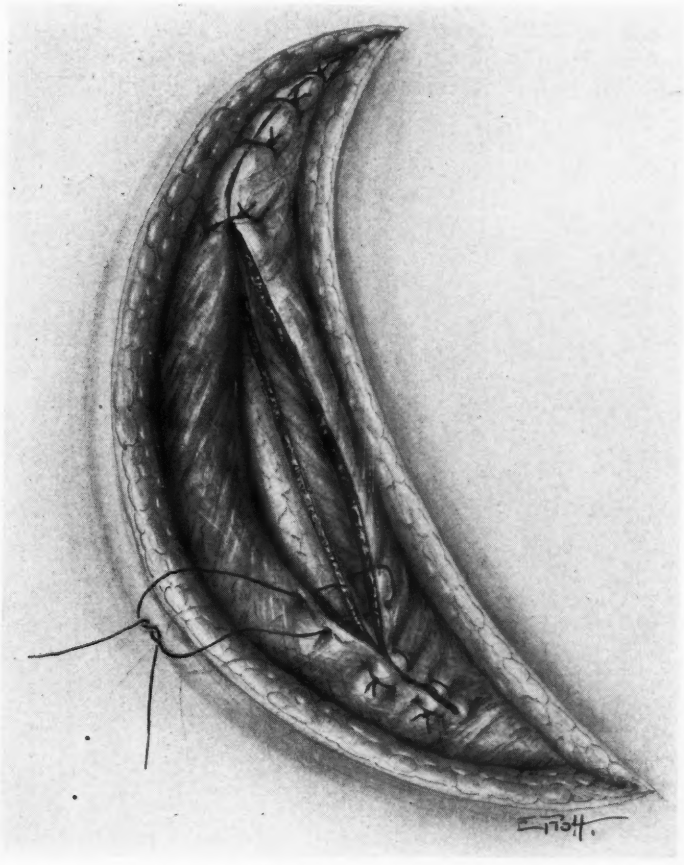

Fig. 4.—Diagrammatic drawing of the method of suturing the cephalad segment of the latissimus dorsi to the bed of the eleventh rib and to the belly of the pedicled latissimus dorsi where it crosses the twelfth rib to enter the thoracic cage.

lungs were symmetrically aerated. Successive barium swallows showed that for the first nine weeks after operation the esophagus was not displaced. Thereafter, however, the esophagus deviated to the left. This observation was better understood when autopsy examinations were carried out. Dogs sacrificed within

two months of operation had well-healed suture lines and only moderate atrophy of the pedicle of the skeletal muscle of the latissimus dorsi. By the fifth postoperative month the pedicle had atrophied to about one third of its original bulk, and in so doing had stretched whatever medial remnant of the diaphragm remained to bridge the distance. The pericardium was not significantly pulled over, but the esophageal hiatus was displaced. There was, however, no sharp angulation or obstruction to the esophagus, and esophagogastric motility was not altered. Although the esophageal hiatus was moved, it did not appear enlarged, and no hiatus hernias were detected. Of the seventeen successful experiments, only one had a small incisional hernia close to the lateral thoracic cage; this was 1 × 1.5 cm., and contained a freely movable tab of omentum. Microscopic examinations of tissue taken from the suture line showed dense fibrous scar tissue bridging the diaphragm to the latissimus dorsi. Segments of the latter muscle showed early fatty degeneration and subsequent replacement fibrosis (Fig. 7).

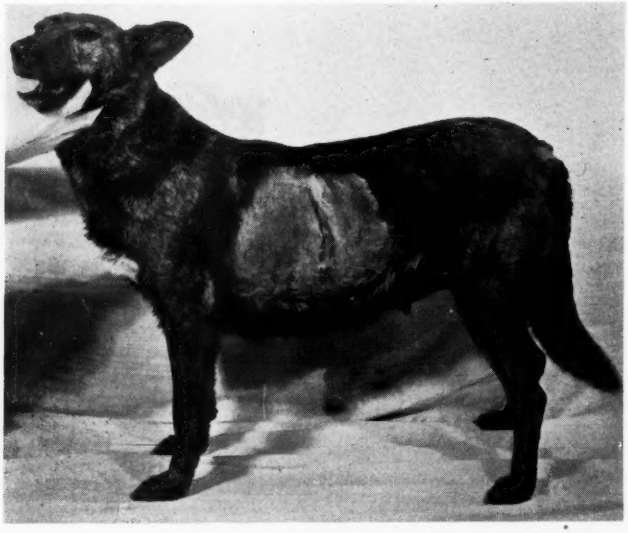

Fig. 5.—Photograph of dog 11 illustrating the concavity of the chest wall at the site of the rib resection.

DISCUSSION

Numerous papers have appeared discussing the relative merits of transthoracic and transabdominal approaches to the diaphragm for repair of hernial defects. For many years Truesdale[2] has advocated the thoracic route in all cases, and in his hands this method has achieved good results. On the other hand, Donovan[3] favors the abdominal approach through a subcostal incision, while Harrington[4] employed a rectus incision. Both these men emphasize the facility with which viscera can be drawn down and rearranged in the abdomen. Ladd and Gross[5] likewise favor the rectus approach and in their hands even

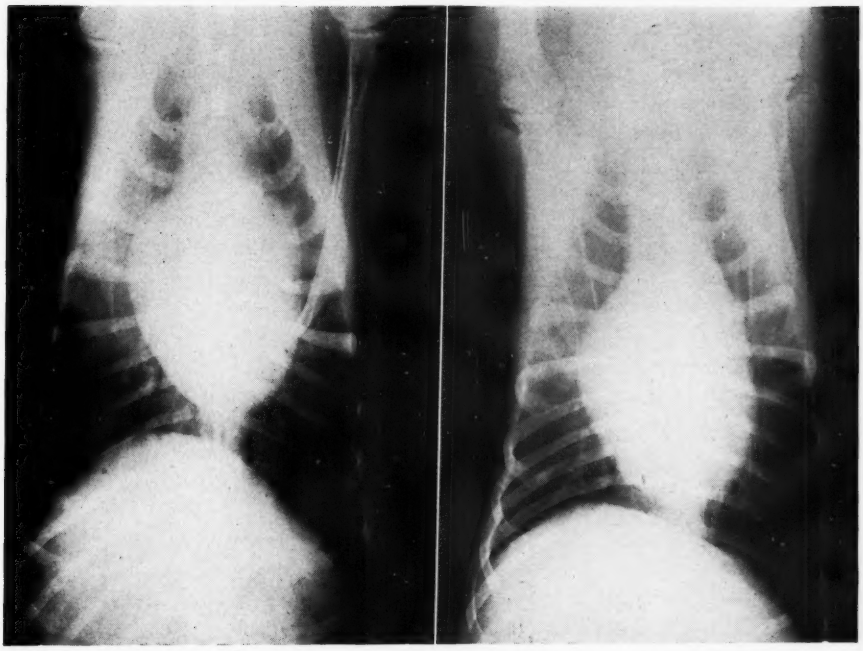

Fig. 6.—X-rays of the thorax of dogs 7 and 11 illustrating the flattened left diaphragm, three and ten months after operation.

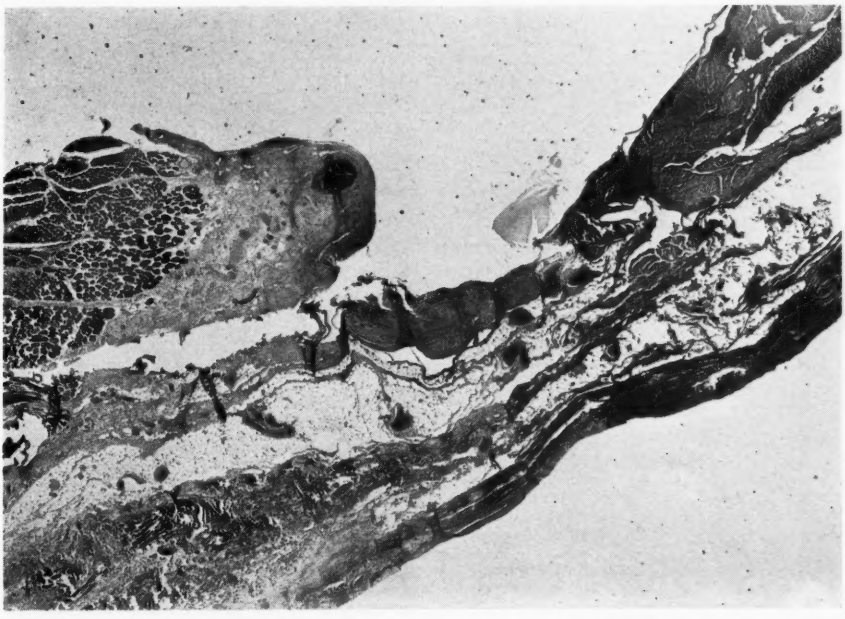

Fig. 7.—Microphotograph (×60) of the suture line where the pedicle of the latissimus dorsi joins the remnant of the diaphragm. The voluntary skeletal muscle of the pedicle has been replaced by dense fibrous scar tissue.

large defects can be closed well by this route. When the abdominal cavity appears too small to receive the viscera without increasing the tension on the diaphragmatic repair, they recommend closing only the skin of the abdominal incision and repairing this incisional hernia at a second operation. Dorsey[6] pointed out that the anterior abdominal wall might easily be stretched manually with a rectus incision, thus enlarging the abdominal cavity and avoiding the necessity of a two-stage operation. Hedblom[7] wisely indicated that both the abdominal and the thoracic approaches had their special merits and limitations, and that the selection of the method in each instance should depend upon the anatomic and clinical type of hernia.

Most hernial defects of the diaphragm are quite small and enable any of the conventional methods of repair to be carried out without difficulty. Operators usually freshen the edges of the defect and join opposite sides with interrupted mattress sutures. Upon occasion, posterolateral defects are unusually large, and the remnants of diaphragmatic tissue are narrow. In these instances, conventional methods of repair fail.

From the experimental studies presented here, it appears that large diaphragmatic hernias, particularly in the posterolateral region, can be satisfactorily repaired without tension on the suture line by dividing the latissimus dorsi in such a fashion that a pedicle of the caudal portion can be mobilized and swung into the chest to aid in closing the diaphragmatic defect. The cosmetic effect is satisfactory. The muscular function of the shoulder is unimpaired.

SUMMARY

A transthoracic repair of experimentally produced diaphragmatic hernias has been investigated in eighteen dogs. The divided latissimus dorsi has been introduced into the chest on a pedicle and has been utilized to close large diaphragmatic defects which otherwise could be closed only with great tension. The fate of voluntary skeletal muscle in such a procedure has been observed.

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